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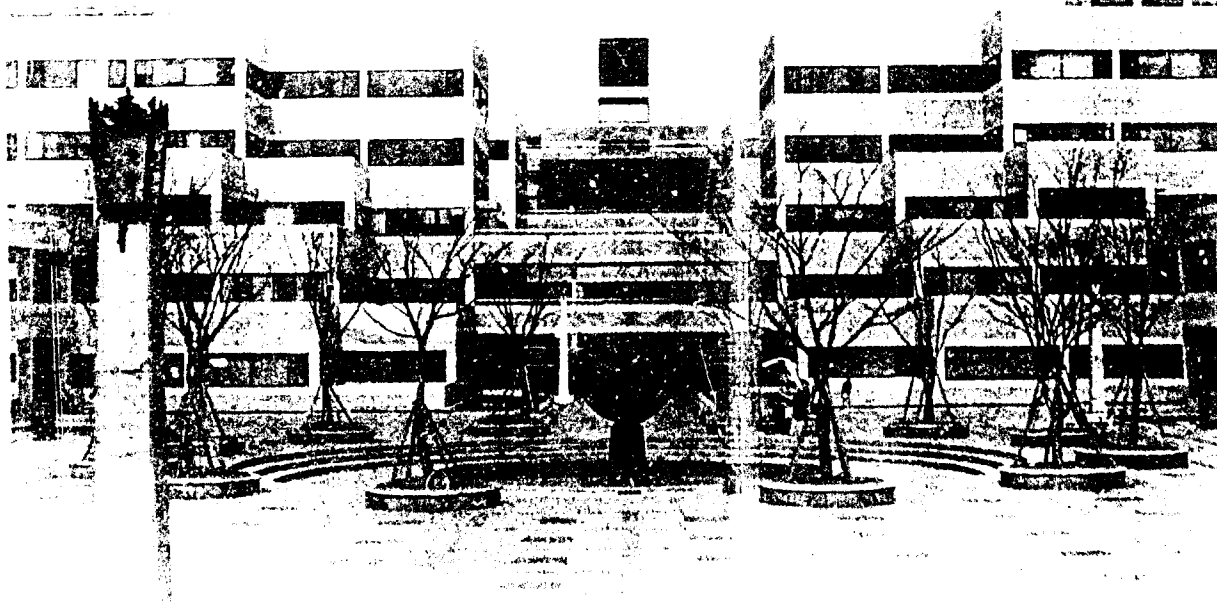
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CONTENTS

Page

| | |
|-------------------------------------|---|
| Scientific Information Briefs | 1 |
|-------------------------------------|---|

Computer Science

| | |
|---|---|
| Snapshot of Computing Activities in Korea | 7 |
| David K. Kahaner | |

This article provides a "snapshot" of computing activities in Korea, including an assessment of parallel processing projects at the Pohang Institute of Science and Technology and the Korea Advanced Institute of Science and Technology.

| | |
|----------------------------------|----|
| Nippon Steel Kimitsu Works | 15 |
| David K. Kahaner | |

This article describes to what extent automation and computerization have been accomplished at the Kimitsu Works of Nippon Steel.

| | |
|---|----|
| The First International Workshop on Algorithmic Learning Theory | 19 |
| David K. Kahaner and David Haussler | |

Algorithmic learning theory is the theoretical portion of artificial intelligence that is concerned with machine learning. This article summarizes the major papers presented at the workshop.

| | |
|---------------------------|----|
| Computing in Taiwan | 23 |
| David K. Kahaner | |

Computing in Taiwan is discussed by describing two meetings at National Tsing Hua University, the International Computer Symposium and the First Workshop on Parallel Processing, as well as a visit to the Institute for Information Industry.

| | |
|--|----|
| New Information Processing Technology Workshop | 31 |
| David K. Kahaner | |

This workshop was organized to discuss aspects of a possible Japanese new 10-year program to follow the Fifth Generation Institute for New Generation Computer Technology program that is to end in 1992. A summary of the discussions is presented and some opinions about the directions that this program might take are given.

| | |
|---|-----------|
| New Information Processing Technologies Symposium (Sixth Generation Project) | 45 |
| David K. Kahaner | |

NIPT, the successor to the Fifth Generation Project, is described.

| | |
|--|-----------|
| The First Japanese Knowledge Acquisition for Knowledge-Based Systems Workshop | 53 |
| David K. Kahaner, B. Chandrasekaran, and Hiroshi Motoda | |

Knowledge acquisition (KA) covers a broad area, and the talks presented at this workshop reflected the breadth of the subject matter.

| | |
|--|-----------|
| SX-3 Benchmarks from Swiss Team Tests | 57 |
| David K. Kahaner | |

This article presents the benchmarks from Swiss team tests on the NEC SX-3/12 and SX-3/14 supercomputers.

| | |
|--|-----------|
| A Review of Japan and Japanese High-End Computers | 59 |
| Sverre Jarpe | |

The latest supercomputer systems offered by NEC, Fujitsu, and Hitachi and their operating systems and current installed base are described, with a comparison to the European supercomputer installed base. The author tries to predict what will happen in Europe in the large-scale computing area over the next few years and suggests how best to profit from the situation.

Materials Science

| | |
|--|-----------|
| Welding Technology in Japan and Korea | 81 |
| Glen R. Edwards and Stephen Liu | |

This article briefly describes the First Japan-U.S. Symposium on Advances in Welding Metallurgy and a series of visits to industrial and academic research institutes in Japan and Korea.

Ocean Science

| | |
|--|-----------|
| Oceanography in Indonesia | 91 |
| David Evans | |

Indonesia's present and projected oceanographic research topics and its plans for cooperative projects are described.

| | |
|--|-----------|
| The U.S. Navy and Oceanography in India | 93 |
| Bernard J. Zahuranec | |

This article describes the present and projected oceanographic research efforts in India supported by the Office of Naval Research and India's participation in Prof. Munk's Heard Island Experiment.

| | |
|---|-----------|
| The Office of Naval Research/National Academy of Sciences International Lecture Series | 97 |
| Bernard J. Zahuranec | |

In an attempt to increase the exchange of information between U.S. and foreign scientists, the National Academy of Sciences, through the sponsorship of the Office of Naval Research, has initiated an international lecture series, in which distinguished U.S. scientists will speak on topics that are the "cutting edge" of science. This article describes the inaugural lecture of this series, given by Prof. Walter H. Munk of the Scripps Institution of Oceanography.

Superconductivity

| | |
|---|-----------|
| Recent Progress in High Temperature Superconductivity as Reported at the International Symposium on Superconductivity (ISS'90) | 99 |
| Donald H. Liebenberg | |

ISS'90 represented a showcase of recent results in basic, technological, and applied areas of both high temperature and low temperature superconductivity. This article surveys only a modest portion of the research presented in areas of physics and chemistry, films, wire, tapes, bulk materials, and applications.

| | |
|--|------------|
| Superconductivity Research at Japanese Laboratories | 109 |
| D. Liebenberg, S. Wolf, M. Nisenoff, D. Gubser, and F. Patten | |

Superconductivity research at several Japanese laboratories is discussed.

Cover: The Pohang Institute of Science and Technology (POSTECH) was established by Pohang Iron and Steel Company in 1985 with the explicit aim of creating a world class research university. This photo of the POSTECH campus was donated by Prof. Chan Mo Park, Chairman of the Computer Science Department (see D.K. Kahaner's article on computing in Korea on page 7).

SIBRIEFs

Scientific Information Briefs

PARALLEL PROCESSING PROJECTS AT THE ELECTROTECHNICAL LABORATORY

EM-4

The EM-4 is an 80-node, distributed memory, coarse grain dataflow machine that is a prototype for a 1,000-node version. By coarse grain, I mean that blocks of Von-Neumann, register-based code are connected by dataflow arcs. This mixed model provides the advantages of dataflow (flexible, dynamic scheduling) at the upper level of a program and of Von-Neumann machines (static register scheduling) at the lower levels. As many parallel programs have this type of architecture, this appears to be promising.

The low level, register-based part of this architecture is RISC based. The RISC pipeline is integrated with the dataflow loop so the two parts work quite well together (see experiment below). All of the hardware for one node (including communications) is built into a single gate array chip. The clock cycle is 80 ns. Although there is no floating point in this prototype, there will be in the next version.

The other part of the architecture is the communications network. Each processor is one node in an omega network. The communications network is designed to support dataflow computations and therefore is designed for very fine grain communications. A word can be sent or received in a single instruction. Messages propagate through the network at one word per node per clock cycle (80 ns). The really nice feature of this is that the user does

not need to worry about packing up words into contiguous memory buffers before sending a message. Messages are typed by both destination memory address and category. Example categories are "data message" or "create process." The user may define these categories.

I wrote a program to illustrate some of these features. The test was a smoothing algorithm that worked on a vector. It is an iterative algorithm in which the next value of each element of a vector is a function of the previous value and the two neighboring values. This generates communications that are similar to many numerical problems (partial differential equations (PDE), etc.). In a sense, the test I wrote is not ideally suited for dataflow machines. It is more of a data parallel algorithm, which is more ideally suited for a single instruction/multiple data (SIMD) machine like the CM-2.

The program consisted of placing a "process" (or whatever the equivalent idea is for dataflow machines) on each node, which iteratively (10,000 cycles) received the values from the two neighboring processors, added them together, and sent the results to the two neighboring processors. So messages were one word long and there were lots of messages. The results of the test were that it took 36 clock ticks to perform each cycle. (The EM-4 has a wonderful timing facility that counts clock ticks.) During each iteration two words were sent; at 80 ns/cycle, this corresponds to 1,440 ns/word or 360 ns/byte (this also includes the integer add). This compares quite favorably to 390 ns/byte on an IPSC2 with messages long enough to overcome message startup costs (greater than 20K bytes).

Questions about the EM-4 can be directed to Shuichi Sakai (sakai@etl.go.jp).

CODA

CODA is still in the paper stage. It is a distributed memory machine that is designed for real time applications. This machine looks much less like a dataflow machine than the EM-4. The interesting aspects of CODA are in the communications hardware.

Message priorities have been added to support real time applications. Within the communications hardware, messages with higher priority are routed before lower priority messages.

To me, the most interesting aspect of CODA is the register level synchronization. Each memory location and register contain full empty bits, which are used to implement produce/consume semantics on all memory and register access. In conjunction with this, a send or receive instruction can target any memory element or register on any processor. Message packets to read or write memory or registers are inserted into the RISC instruction pipeline along with instructions from the local processor. The result should be very fine grained communications with very little overhead.

In order to keep the processors busy, there are several instruction streams supported by the hardware. Processes that block on memory or register accesses can be swapped out and another instruction stream swapped in in a few clock cycles.

These three constructs, message priorities, register level synchronization, and multiple instruction stream

support, should greatly improve communications on distributed memory multiprocessors. Questions can be directed to Kenji Toda (toda@etl.go.jp).--*Matt Rosing, University of Colorado*

SECOND FUZZY LOGIC SYSTEMS INSTITUTE HARDWARE PRACTICE SEMINAR

Summary

The seminar consisted of three parts (a fourth part, an introduction to the usage of the rule and defuzzifier chips, was canceled because of lack of time). In the first part, the basics of fuzzy system theory were explained, stressing the need to incorporate concepts of vagueness into the description of complex systems, where purely symbolic methods were not sufficient.

In the second part, a concrete example of a control system was given, where using fuzzy methods turned out to be easier than traditional ones. The approach to the original problem, to balance an inverted pendulum, is cited rather often recently and belongs to the repertoire of many talks about fuzzy theory. The usual claim, however, that controlling an inverted pendulum by classical methods is nearly impossible and hence fuzzy control is necessary, seems to be an exaggeration, since there is at least one system I know about (at Fraunhofer Society in Karlsruhe, Germany) that dates back some 5 years. Prof. Yamakawa extended the problem into that of balancing a full glass of wine standing on a rod, which itself stood on a movable cartridge, and asked his students to build a fuzzy control system for it. Some 20 students in their second and third university year, with no experience in classical control theory, were given a printed board with three

rule chips and one defuzzifier chip, an equivalent of 24 school hours, and a budget of ¥5,000. The system was completed just the day before the seminar. The fuzzy rules were similar to: "If the rod is leaning to one side VERY MUCH, move the cartridge FAST to the other side" (capitalized words indicating fuzzy variables). With no knowledge of control theory, it took the students a lot of experimentation with the rules and the underlying membership functions to complete the system.

The third part was on fuzzy logic control and its realization as electronic circuits. Each fuzzy variable of a rule is modeled as a membership function. Within the rule chips of Yamakawa/Omron Tateishi, a membership function is a piecewise linear function with values between zero and one, represented approximately by seven discrete values between 0 and 5 volts, ranging on an abscissa of 25 points, usually between -5 and +5 volts. The graph of a typical membership function is triangular or trapezoidal with five parameters of variation: abscissa of highest point and angle of both rising and falling slope and maximum of the function.

Inferring a conclusion from a set of facts by using fuzzy rules is done in the following way, assuming that the premise of a rule consists of logically ANDed predicates: The membership function of each predicate of a rule is evaluated at the point given by the fact. Next, the minimum of the obtained values is taken. The membership function representing the conclusion of the rule is then truncated at the height of that minimum. This procedure is done for each rule and the truncated membership functions are combined to one function by taking the maximum of these functions. The resulting membership function represents the conclusion of the given facts. This is done by fuzzy rule chips, one for each rule, and a MAX-circuit. Now, the concluded

membership function must be turned into one single value, the "essence" of the concept represented by that function, by using the defuzzifier chip, which computes the center of gravity of the (graph of the) function. Inference speed of the rule chip is 1 μ s and that of the defuzzifier chip 5 μ s.

All in all, the seminar was very interesting and instructive. No advanced frontline research results were taught and the material distributed was about 2 to 3 years old, but the seminar helped to "defuzzify" the fuzzy-hype of certain magazine reports and was one measure of educating the public about this new technology.

Comments

The participants of the seminar were all in their 30s to 50s, apparently not coming from an academic environment alone. This shows the awareness of the general public in Japan of the concept of fuzziness (because of the intensive media coverage and product advertisements about "fuzzy"). I won't discuss whether this is also due to cultural influences--in Japan vagueness comes not necessarily with uneasiness. If, on the other hand, this awareness is only superficial and without real understanding, there might be some danger in applying fuzzy theory to real world problems. The seminar, at least, also made clear some of the weak points of the present fuzzy technology. Some examples follow.

If an engineer uses the Yamakawa/Omron-chips or possibly other chips, he/she will have to deal with constraints of that hardware, and might even be unaware of that. One constraint is certainly that the rule chip can handle only special forms of membership functions: trapezoidal functions with 5 determining parameters, discretely approximated on 25 equidistant abscissa and 7 ordinate points. Not being an expert, I wonder whether this might be a severe restriction.

Another constraint built into the hardware is the way the defuzzifier interprets the inferred membership function by calculating its center of gravity. First, there are other methods of defuzzification like center of support, center of maximal area, or half area median. Second, computation of the center of gravity usually involves division of a weighted area by the whole area of the functions graph. To avoid complicated division circuits in the chip, Yamakawa chose to modify the original membership function to make its area equal to 1 by shifting it along the ordinate (and truncating at zero), which is accomplished in the chip by a feedback circuit; this process, which is much easier to implement in silicon than a division, generally changes the center of gravity, since some area is cut away, the effect of which is unknown (to me). Third, by defuzzifying a membership function into a single value, here the center of gravity, quite different functions are interpreted identically, like a function pair representing MEDIUM SIZE and EITHER SMALL OR BIG SIZE, or even negated symmetric functions for MEDIUM SIZE and NOT MEDIUM SIZE.

Another point of caution in the usage of the chips implementing fuzzy rules is the choice of membership functions for a rule and the distribution of the functions along the abscissa. If, for example, there is a fact for which no rule fires (i.e., no membership function has a nonzero value at the given point), the whole system might react in an unpredictable and chaotic way. This chaotic behavior does not seem to be well understood and might cause calamity.

Different from classical general purpose computers, which can be programmed with some effort *ad libitum*, this kind of hardware has built in various constraints, and a lot of care is needed when using it. Although these constraints have not been addressed explicitly, sometimes only declared as

necessary for easier implementation in silicon, the seminar helped to show "what's what" about those fuzzy chips one hears about so often recently and that there is still room for research. This need for further research and a certain concern about the recent fuzzy boom in Japan, where "fuzzy" is a fashionable catchword building an image of an easy-to-use technology, well suited to the Japanese, solving many if not all problems left over from classical technologies, were reasons for Prof. Yamakawa to initiate the formation of the Fuzzy Logic Systems Institute.--
Thomas Hagemann, GMD

COMPUTER RELATED PROGRAM PLANS FROM THE MINISTRY OF INDUSTRIAL TRADE AND INDUSTRY (MITI)

Today there are more than 320,000 multipurpose computers in Japan, and its "information industry" was at the ¥24 trillion level last year. It is projected to be ¥140 trillion by year 2000 (more than \$1 trillion), accounting for 20% of Japan's GNP, and be the nation's largest industry. MITI wants to network all sectors of society together. They have identified four major hurdles to be overcome:

- (1) shortage of software specialists
- (2) lack of interoperability among incompatible systems
- (3) concentration of computers and skills in Tokyo, and sparsity elsewhere
- (4) computer security

A number of programs with both direct funding and tax incentives have been implemented this year (1 April 90 to 31 March 1991) to deal with these problems.

- (1) Strengthening software supply base in regional areas.
 - Training of regional talent.
 - Creation of system for smooth development and supply of software.
 - Development and distribution of multipurpose programs and databases.
 - Promotion of use of computers in schools.
 - Strengthening/expansion of SIGMA system.
 - Model future info age cities such as Tokyo bay coastal districts, Kansai New International Airport districts, Osaka South Bay.
 - HDTV local promotion.
- (2) Networking society and maintaining user base.
 - Give OSI (Open System Interconnection) the same status as JIS (Japan Industrial Standard).
 - Use info systems to promote active participation of elderly in society. (Japan expects a 50% increase in GNP by year 2000 with a 3% drop in population.)
 - More human interfaces, such as graphics, analog, Japanese language.
 - Promote networking in industry.
- (3) Promotion of information related technology.
 - Research and development (R&D) on Fifth Generation Computer (prototype complete system and trial manufacture of partial system).

- Comprehensive survey of neural computers, biocomputers.
 - R&D on interoperable database systems (multimedia, distributed).
 - R&D on new function devices to look beyond limitations of semiconductors (superlattice devices, three-dimensional devices, biocomponents).
 - R&D on superconducting materials and devices (high temperature, thin films).
 - Research on new software structuralization model.
 - Development of medical diagnosis support system.
 - Basic technology research promotion center.
- (4) International development of the "info age" in developing countries.
- Cooperative research in machine translation (Japanese, Chinese, Thai, Malay, Indonesian).
 - Training (Japanese technicians sent to developing countries).
 - CAI system implemented with Singapore (focus on advanced software writing technology, knowledge information processing technology).
- (5) Database development.
- Building major databases in Japan and dissemination outside.
 - Building official databases (technology, patents, small/medium businesses).

--David K. Kahaner, ONRASIA

ROBOTS IN JAPANESE INDUSTRY

The key to future Japanese manufacturing success is to move from production of a large number of the same items (a few large assembly lines) to production of many smaller lots of different items (many small assembly lines, customized assembly, flexible manufacturing). Mass production of large-lot items will move to less labor-expensive countries. If assembly line and other production operations can be changed rapidly and inexpensively by using highly automated and intelligent techniques, it will be possible to produce customized lots economically. Robots are an important part of this strategy. Robots differ from conventional automated machines in their flexibility and include functions such as locomotion, mobility, grasping, recognition, etc. Prototype robots were developed in the United States in the late 1950s and in Japan in the 1960s. The Japan Industrial Robot Association (JIRA) was established in 1972 to aid in robot diffusion into industry. Various Japanese Government policies have also aided this diffusion, including special leasing arrangements, depreciation system, tax breaks, loans, and grants.

Since 1978 Japanese industrial robot production has grown from \$140M to over \$3.6B in 1990, more than 20-fold. Exports of industrial robots have gone from essentially zero in 1978 to about \$800M in 1990, about 20% of total production. The largest producers of industrial robots (1989) are Matsushita Electric Industry (MEI) (16.5%), Fuji Machine Manufacturing (8.3%), Fanuc (5.4%), Yasakawa Electric Manufacturing (5.3%), and Kawasaki Heavy Industries (3.4%), accounting for about 40% of all production.

At present almost all industrial robots are used in manufacturing. About half of all shipped robots are for automotive or electrical machinery production. The first major robot user was the

automotive industry, for painting, welding and loading, but this industry now absorbs about 20% of robot production. Honda's #3 Suzuka line is 2,600 feet long, compared to Detroit's average of 7,600 feet. This is a crucial item in Japan, but in any case shorter production lines mean less capital is required for new buildings, and old facilities can support higher production. Nissan is introducing the intelligent body assembly system (IBAS), which combines 51 computer-controlled sensors, jigs, and welding robots in a single unit. It produces eight different models on the main line without any retooling and produces a partially assembled car every 45 seconds. Honda can produce four models on one line, something the United States still cannot do.

The electrical machinery industry now absorbs about 35% of robot production. Robots are essential for use in dust-free (clean room) environments and for small volume flexible manufacturing systems such as needed for video cameras, PCs, etc.

The key driving force for robot use, however, is Japan's labor shortage and aging work force; in 1990 about 9% of Japanese workers were over 65, by 2000 it will be over 15%. Fewer Japanese are interested in manufacturing careers. Labor unions have seen robots as eliminating dangerous jobs, and displaced workers are usually moved to other positions within large, integrated Japanese companies. Finally, labor costs in Japan are very high, about 5% more than in the United States and over 50% higher than in England.

About half of the Japanese manufacturing companies have invested this year in facilities and equipment to improve efficiency, specifically robotization and automated manufacturing systems. This was one of the leading methods cited for coping with labor shortages, and the method claimed to be most effective. Interestingly, investments that cut labor costs were essentially flat from 1984-1987 but then rose

about 20% in each of 1988 and 1989. Research and development (R&D) investments also increased about 20% in each of these two years.

[This is very high compared to more general industry. For example, a survey of 16,000 corporations, universities, and research institutes showed that R&D investment increased 11% in 1989. Hitachi devotes 15% of sales to R&D. Any way you slice it, R&D investment in Japan is large, estimated about 3% of the gross national product (GNP) in 1989, now surpassing that of Europe, and on a per capita basis it is almost as much as that of the United States.]

All Japanese robot producers are expanding capacity. Fanuc will triple its capacity when its Oshiwo plant opens, Toshiba will increase production by 20%, Yasakawa Electric Manufacturing is building a new \$20M plant, Nachi-Fujikoshi will increase automotive robot assembly 40%, etc. JIRA has made the following estimates for robot production.

| | |
|------|---------|
| 1991 | \$ 4.3B |
| 1995 | \$ 6.5B |
| 2000 | \$11.9B |

They also predict that wide use of robot technology is expected in

- Nuclear safeguards
- Medical assistants for bedridden and handicapped
- Ocean exploitation, handling, machining, surveys
- Agriculture and forestry, fruit harvesting, crop dusting, lumbering
- Construction, assembly of reinforcing bars, bridge painting, finish work in high-rise buildings
- Metal and coal mining
- Transportation

Three Government programs that deserve attention are:

1. Robots in extreme environments, will end 3/91, focused on robot use in nuclear power plants, ocean, disaster, petroleum (\$145M).
2. Micromachine technology, 1991-2001 (\$181M) to develop micro-technologies for medical and industrial applications. Just beginning.
3. Intelligent manufacturing systems (IMS), computer-integrated manufacturing, standards, etc. Just beginning.

Robots are going to be an important component of Japan's technology exports. These have already jumped 33% (to \$2.5B) between 1988 and 1989 and are now almost equal to technology imports. (Exports are to the United States, Korea, China; technology imports are primarily from the United States and Europe.) Technology exports to Asia are about 40% of the total.--
David K. Kahaner, ONRASLA

* * * * *

SNAPSHOT OF COMPUTING ACTIVITIES IN KOREA

In October 1990, the author traveled to Korea to attend a Korean Information Science Society (KISS) meeting and to visit Pohang Institute of Science and Technology (POSTECH), Korea Advanced Institute of Science and Technology (KAIST), Korea Standards Research Institute (KSRI), and Korea Institute of Science and Technology (KIST). The meeting is briefly discussed, and the computing activities at the research institutes are described. Some assessments of parallel processing projects at POSTECH and KAIST are also given.

by David K. Kahaner

BACKGROUND

Computing activities in Korea are concentrated in three major areas:

- (1) Seoul and suburbs. This includes many major and minor universities, government institutes, laboratories, etc. Seoul is on the western coast of Korea, facing the Yellow Sea, which in turn separates Korea from mainland China.
- (2) Pohang and Pusan. Both are on the southeast coast facing Japan, about 1 hour by air from Seoul. Pohang is about 350 km from Seoul. The water between Japan and Korea was called the Eastern Sea but later renamed the Japan Sea after Japan occupied Korea earlier this century. Pusan is a large industrial port city; Pohang is the site of Pohang Steel Company's huge steel plant and also of POSTECH.

- (3) Taedok Science Town. This inland town is about halfway between Pohang and Seoul. Originally this was a suburb of the adjacent city of Taejeon but has now developed an identity of its own. Taedok has some of the same feel as Tsukuba, the Japanese science center. I was told that Taedok was set in its present location (south of Seoul) to be out of range of attack from North Korea, although this is surely not the situation any more. The English spelling of both Taedok and Taejeon often begins with a "D."

The coordinator for my visit was

Prof. Chan Mo Park
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Prof. Park also headed the Computer Science Program at the Catholic University of America, in Washington, DC, and he is currently on leave from there. I have known Chan for many years, although this was my first trip to Korea and also my first to see him in a non-Washington environment. He has either been a classmate, teacher, or close personal friend of almost all the key people in Korean computing science and technology, including the Minister of Science and Technology. Computing is seen as a key technology for the future, and computing related issues are highly visible. Because Korea, with a population of about 42 million (Republic of Korea only), is still a technologically emerging country, the community of scientists is relatively small, and communication among them is very strong. Almost all the people I spoke to knew each other and their current projects. Senior people often come together in Seoul for various policy meetings, perhaps several times each month. Thus as in Japan, personal contacts take on a highly significant role. My own visit was far too brief to

provide a realistic analysis; hence, I have titled it a "snapshot." I saw it as an opportunity to learn a bit about the country, meet some people, and get a general orientation to computing research. I expect to return in the spring of 1991 for another look, in more detail. Nevertheless, without Park's help I would have seen far less and I am sincerely grateful for his enthusiastic assistance.

KOREAN INFORMATION SCIENCE SOCIETY

The Korean Information Science Society (KISS) semiannual meeting was held at the "Korean West Point" just outside Seoul. I had the opportunity to meet several of the Society's officials:

Exiting President

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Dean, Graduate School of
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New President (former Vice President)

Professor Ha Jine Kimn
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and

Mr. Hee Yol Yu
Director General
Technology Policy Office
Ministry of Science and Technology
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There were three invited lectures including my own, which surveyed parallel processing in Japan. One was given by Chan Mo Park, emphasizing

the need for computing to reach out to all aspects of society. The opening speech was by

Young-Hwan Choi
Vice Minister
Ministry of Science and Technology
Korea
Tel: 503-7604

The remainder of the first day's meeting schedule was given over to society business such as installing the new officials and thanking the outgoing ones. Currently KISS has several thousand members. There are about 100 colleges and universities in Korea, although many fewer with significant research activities. The second day was composed of tutorials and contributed presentations. I attended a tutorial on fuzzy logic by

Professor Kyung Whan Oh
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Seoul 100-611 Korea
Tel: 715-0141-7 x384
Fax: (02) 718-4218

All the lectures except for mine were in Korean. In the Proceedings, a few of the printed papers are in English. There were a large number of students at this meeting. Without being able to understand the papers in detail, I sensed that this was a good opportunity for many Korean scientists to present progress reports of their work, although I suspect that the best work is saved for publication in English language journals. As far as I could tell, there were no papers in numerical computation presented at this meeting, exclusive of those related to image processing and some aspects of neural net computation such as character recognition. In many ways the written Korean language is easier than Chinese or Japanese (which is essentially Chinese), as there are far fewer symbols and they have a form of alphabet. There is a good deal of Korean

research in character recognition, vision, and robot motion, but I simply did not have enough time to assess this in detail.

POHANG INSTITUTE OF SCIENCE AND TECHNOLOGY (POSTECH)

Several Korean scientists complained to me about the level of support for scientific research at national (federally funded) universities. Some of the most ambitious research projects are being conducted at private universities, and these are often established by large, well-financed corporations. POSTECH is a premier example, established by Pohang Iron and Steel Company in 1985 with the explicit aim of creating a world class research university. The brand new 350-acre campus is located on a very much larger parcel of land owned by Pohang Steel. This is really a mini-city, and it contains housing, recreation, and school facilities for POSTECH students and faculty as well as for Pohang's employees. The grounds are beautifully maintained and one gets the feeling of living in a park rather than near a steel mill. I didn't even see the mill during my visit, except driving from the airport. I was told it is one of the largest in the world. During my next visit I would like to arrange for a tour inside.

Pohang's president realizes that steel making will taper off as a major industry within the next 10 years and hopes that some of the technology by-products of POSTECH will be directly useful as the company diversifies. (Pohang is the fifth largest steel maker in the world.) POSTECH's first freshmen class of 250 was matriculated in 1987 with about 80 faculty. The total number of undergraduates will grow to about 1,200 along with about 1,000 graduates. The student-to-faculty ratio is planned to be less than 3 to 1, with a total faculty of about 300 by the year 1992. The POSTECH model, mentioned to me

repeatedly, is Caltech in the United States, and the hope is that similar quality work will be forthcoming in several years. Undergraduates are chosen from among the top 2% of Korean high school students, and essentially all get 4-year full tuition scholarships. Housing is free and many students get meal stipends. Most graduate students are research or teaching assistants, and all (even married students) get free housing. The bottom line is that any student who is capable enough to be accepted can study at POSTECH without incurring any financial obligation.

Several major research facilities are in place or in the works, including a 2-GeV synchrotron radiation source, wind tunnel, multipurpose pilot plant for the chemical engineering department, and a supercomputer installation. The computer center director feels he has the support to purchase a large Convex or small Cray class machine within the next year. At the moment the center has a Vax 8800.

I spent 2 days at POSTECH. I've never seen a better endowed facility considering that it has been open less than 2 years, and some buildings are still under construction. Faculty offices are large, bright, and modern. Sun, Apollo, and Silicon Graphics workstations are generously sprinkled in offices, and laboratories appear as well equipped as new universities in the West. Electronic mail is working, mostly. Almost without exception the faculty consists of people who have a Ph.D. from a Western university, or who have spent substantial time in the West. For example, in the September 1987 POSTECH faculty list (its first), the Math and Computer Science Departments contained faculty from the University of Michigan, Wright State University, Oregon State University, State University of New York at Stony Brook, Bell Labs, Compiegne University,

Northwestern, University of Maryland, and Iowa State. The other departments are Physics, Chemistry, Engineering and Materials Science, Mechanical Engineering, Industrial Engineering, Electrical Engineering, and Chemical Engineering. They have faculty from the Massachusetts Institute of Technology, Caltech, Stanford, Delaware, University of Massachusetts, Rice, Columbia, Tulane, University of Texas-Austin, University of Pennsylvania, Indiana, Virginia, Indiana, Brown, North Carolina, Berkeley, Michigan, Carnegie-Mellon, Case, Georgia Tech, Princeton, and similar excellent Western universities. The faculty I met all speak English extremely well and typically have some active collaboration with a Western scientist. For example, I had an interesting conversation with

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who has is doing research on dynamics, chaotic attractors, etc. jointly with colleagues in the Physics Department at Cornell. He showed me an extremely comprehensive and well thought out package that was running on his SGI. I had a few quibbles with the numerical integration techniques that he was using, but the interface itself was as good as any I have seen elsewhere. The Computer Science Department is also engaged in robot motion planning. Similarly, I had a long discussion with Professor Kun Soo Chang, from the Chemical Engineering Department, about the software contained in the Numerical Recipes book, and it was obvious that he was quite familiar with the techniques that are in common use in the United States.

On the POSTECH campus is the affiliated Research Institute of Industrial Science and Technology (RIST). This is an independent research laboratory that is also supported by Pohang Steel. Many POSTECH faculty members have some joint appointment at RIST; I did not have any opportunity to visit this facility.

Faculty members are treated at least as well as the students, with free housing and, for many, free automobiles. Their package is extremely generous and accounts for the large number of qualified young professors who have been attracted there. The Western connection is obvious in other ways, too. On the campus, Pohang has built a large log cabin and set it up as a student/faculty beer hall. I had a wonderful evening drinking beer and eating pizza, and it was great fun to watch the Korean students eating popcorn with chopsticks.

The Westernizing of POSTECH's faculty means that international exchanges are expected. The school administration has already begun to build the mechanisms for these by signing agreements with Berkeley, Birmingham, Imperial College, Carnegie-Mellon, Compiegne, and Aachen. This will permit student and faculty exchanges, postdoctoral appointments, and sabbatical years. My impression is that the logistics of a sabbatical would be very easy to arrange, given that POSTECH has access to very comfortable Western housing. It might be a little early, as many of the departments are just getting going, but interested scientists would be advised to look into the possibilities.

POHANG PARALLEL PROCESSOR (POPA)

The most interesting computing research activity at POSTECH is the POPA project, under the direction of

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POPA refers to the POhang PArallel processor, a parallel computer based on 64 INMOS T800 transputers. The origin of this machine is interesting. Queen Elizabeth visited POSTECH when it first opened and gave the university a gift of a single transputer as representative British technology. The Computer Science Department liked it and purchased the others to build the system. A Sun workstation is used as a host with eight root transputers connected to the VME bus. Each user (up to eight) is allocated his/her own domain of processors and input/output (I/O) devices through an interconnection network. Each user can change the topology of his/her domain. To support fast I/O, POPA has a pool of disks that are independent of the Sun file system and these are attached to processors via the three stage interconnection network. The latter is composed of 32x32 cross-bar switches (the mother board contains 2 cross-bar switches). The backplane was built entirely at POSTECH. The POPA group has built a 16-node system and is now building the 64-node system on eight boards. It is possible to extend a POPA system to 256 transputers, which will have about 0.4 GFLOP performance. The network manager, called TRANSMAN, and a unified software environment, called USE, have been developed at POSTECH. For example, on the Sun, the command

POPA -n 64 -c mesh -d 2 -g 2

will give a user a 64-processor mesh configured domain with two disks and two graphic terminals. The POPA project has five graduate students, two researchers, and three faculty. They have been working for about 2-1/2 years and ran a workshop last summer to interest industrial organizations in the project. I watched as POPA ran several benchmarks, including a traveling salesman problem, and integrated $4/(1+x*x)$ to get pi. Their benchmarks indicate that the POPA system is more powerful than early Intel Hypercubes. The idea of a multi-user, dynamically reconfigurable hypercube is not being pursued elsewhere to my knowledge.

My general impression is that POPA will eventually be adapted for use by Korean industry, to a large extent because the POSTECH faculty will be available to consult on its use. It is also potentially helpful in university situations as a way to give students and others experience in parallel processing. It has already been tremendously valuable in this way at POSTECH. The hardware is solid and reliable. As far as I could tell the software looks in good shape as well. One indication is that "real" documentation is available. But POPA will never compete in absolute performance with fast Western parallel computers. I feel that it should be viewed as an effort on the part of the Korean scientists to develop their own expertise rather than to obtain it from outside their country. I saw another example of this in Seoul in the KAICUBE project (see below).

It is much too early to tell if the POSTECH experiment will really produce the same quality research as Caltech. Perhaps it takes decades to emulate the infrastructure and depth of such an institution, but if money can buy success, then POSTECH certainly has what it takes.

TAEDOK SCIENCE TOWN (KIST & KSRI)

I had a very brief tour through the Korea Standards Research Institute (KSRI) and the Korea Institute of Science and Technology (KIST), two institutions located in Taedok.

KIST

KIST boasts the first Cray super-computer installed in Asia (Cray 2) installed in a building that also looks much like a Cray. Their actual machine room is large enough to hold another dozen or so similar sized Crays and was modeled after the installation in Minneapolis. My overall hosts were

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 President
 SERI

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 Director, Computer Systems
 Operation Dept.
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KIST is already thinking about their next machine, although perhaps it will not be a large shared memory super-computer. I was told that management felt that there was some advantage to buying some highly parallel machine, if only to let their scientists learn how to use it. Nevertheless, the KIST scientists were particularly interested in the figures I presented based on research in large memory supercomputers that was part of the Japanese PHI project. Later, they showed me some finite element crash simulations that they

ran in order to demonstrate the Cray's potential to a Korean automobile company. They claimed that the engineers were so impressed that they quickly purchased a machine of their own. However, the Cray is almost entirely used to run existing application software, mostly engineering analysis packages; there is very little software development. I was impressed with the large number of commercial software packages that were running and was told that the agreement KIST had with the Korean Government included a very substantial amount for software purchase and lease on a continuing basis. In fact, it was mentioned repeatedly that if the software money hadn't been forthcoming, KIST would not have purchased the machine. I liked that attitude; we should also stress it in the United States.

KSRI

My visit to KSRI was mostly for general information purposes. It had been arranged because the Koreans knew that I was from the National Institute of Standards and Technology (NIST, the former U.S. National Bureau of Standards). KSRI is a \$32M facility with about 500 staff, including almost 100 with Ph.D. degrees. These are broken down as follows:

| | |
|------------------------------|----|
| Physics | 40 |
| Chemistry | 13 |
| Mechanical Engineering | 12 |
| Electrical Engineering | 5 |
| Chemical Engineering | 4 |
| Materials | 15 |
| Nuclear Engineering | 1 |
| Industrial Engineering | 2 |
| Management | 2 |
| Computer Science..... | 0 |

There are also over 100 staff members with M.S. degrees, but only 2 in computer science. However, a number of the scientists from other fields are working in computing activities. For example, my host

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has been working on graphics standards, and in fact knew about some related work at NIST, in the National Computer Science Laboratory (NCSL). He felt that there was little basic research actually going on in computing at KSRI, and that almost all the work was related to standardization activities. Nevertheless, the scientists at KSRI are heavy computer users, and they are tied in to the Cray 2 at KIST, which is only a few minutes away. (As with many other Korean scientists, Cho has a Ph.D. from an American university, in this case Iowa State.)

KSRI focuses on standards and precision measurement technologies, particularly in physics, specifically to meet the needs of Korean industries. Their work is funded by basic government research funds (30%), contracts from the Ministry of Science and Technology (50%), and contracts with various industries (20%). Projects range from a laboratory for a cesium atomic clock, to more practical ones such as testing techniques to locate defects in composite materials, to the very practical such as vibration and noise reduction in underground power plants.

I also had an opportunity to meet

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Support
Head, Office of Policy Studies
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In Dr. Eun's office there was a prominent display of the NIST organization chart. Although Eun has been to the Gaithersburg laboratory only once, he was well aware of its new name and director, Dr. John Lyons. He also emphasized the role NIST played in the formation of KSRI and the friendly relations between the organizations.

KSRI also participates in various international standards organizations such as the International Organization for Standardization (ISO) and the International Telecommunication Union (ITU) and has numerous memorandum of cooperation with several dozen laboratories around the world. The NIST cooperative agreement was signed in 1981. KSRI also holds an annual workshop on the national standards system and precision measurements, as well as a biennial metrology symposium.

KAICUBE PARALLEL PROCESSOR

My last stop was at the Korea Advanced Institute of Science and Technology (KAIST), a major technical university in Seoul. The specific purpose of this visit was to see a parallel processor called KAICUBE that I had read about in a Japanese newspaper. Its chief developer is

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Vice President
Korea Academy of Industrial
Technology
70-6 Yangjae-Dong
Seocho-gu, Seoul, Korea
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Fax: 577-5488

Unfortunately, Professor Kim was not in his laboratory when I arrived, but several other faculty and graduate students showed the system to me.

KAICUBE is more or less a standard hypercube. KAICUBE I uses a 68020 CPU and 68882 floating point unit. Maximum communication speed is 120M bps. At this time a 64-node KAICUBE II has been built, with peak performance of about 64 MFLOPS. The first machine, with 8 nodes, was completed last year. The group has just begun to build a 128-node machine (KAICUBE III) with the new, faster Intel i860 processor. They estimate that it will be completed at the end of 1992 and will have 5 GFLOP peak performance. It will also have improved communication, up to 320M bps.

The KAICUBE group briefly showed me some of their work on the architecture and software development of the machine, which they have done essentially all themselves. As far as I can tell there are no documents available in English. The little documentation I did see described various applications, such as solving Laplace's equation, sorting, fast Fourier transform (FFT), simulated annealing, and database query acceleration. But I had no opportunity to discuss this with any of the actual users. I was shown the results of one benchmark (traveling salesman problem) in which the KAICUBE II was 2.5 times slower than the Cray 2S. Nevertheless, as this is in almost every way a traditional hypercube, I asked them specifically why build it when they could buy one much more easily. Their answers were frank and illuminating. Basically,

they want to learn how to do it themselves so that they don't have to buy the technology from outside. As far as I can tell this is much the same motivation that drives the POSTECH project. This is an excellent way to train students and develop basic research technology. Its most important use is internal, but the Japanese have shown that this approach can be successful at rapidly catching up with research in more advanced countries. What is not clear, though, is whether, once rough parity has been achieved, breakthrough ideas will also be forthcoming.

KOREA SCIENCE COUNSELOR

I also stopped in for a courtesy visit with

Mr. Kenneth Dewitt Cohen
Counselor for Scientific and
Technological Affairs
U.S. Embassy
82 Sejong-ro, Jongro-ku
Seoul, Korea
Tel: 732-2601, x4210
Fax: 738-8845

Mr. Cohen emphasized that it was very useful for U.S. scientists who were planning to visit Korea to make his office aware of their plans. He has a good overall grasp of scientific activities in the country and can often make excellent suggestions about additional worthwhile travel.

POSTSCRIPT

After I wrote my first draft of this report, Sang K. Cha [chask@eclipse.stanford.edu] pointed out to me that the KAICUBE research project recently moved from KAIST to the Korea Academy of Industrial Technology (KAIT). KAIT was started this year by the Ministry of Commerce and Industry and is led by a Seoul National University

(SNU) professor in international economics. He also felt that SNU and KAIST were Korea's two top universities and that I should be sure to visit them on my next trip. Cha also suggests that during my next visit I should see those organizations that are associated with the Ministry of Communication (MOC). He pointed out that unlike the Ministry of Science and Technology (MIST), MOC controls the telephone company [called the Korean Telecommunication Agency (KTA)] and directs some of its revenue for research in technology and policy. For instance, while the Electronic Telecommunication Research Institute (ETRI), the biggest research institution in Korea, is officially under the supervision of MIST, it is financially under the control of MOC. In addition to KTA, the Data Communication Corp. of Korea operates computer communication networks and leads government computerization projects with ETRI. MOC also established a research institute on communication technology policy and a few other smaller scale research and supporting organizations.

SUMMARY

Korea is far behind Japan and the United States in most computing research but has a very pragmatic view of what they want to accomplish. Essentially, this is to have their own computing infrastructure even if this requires some reinventing of known ideas and technologies. Many senior Korean scientists have been trained or spent substantial time in the West but have returned because of opportunities that did not exist in their own country until recently. Thus they are keenly aware of what is going on outside Korea. At the moment there are few Western scientists (of non-Korean origin) spending sabbatical or other research time there. Relations between Korean and Japanese scientists are cordial, but Koreans have a strong affinity to collaborate with U.S. and European scientists.

David K. Kahaner joined the staff of the Office of Naval Research Far East as a specialist in scientific computing in November 1989. He obtained his Ph.D. in applied mathematics from Stevens Institute of Technology in 1968. From 1978 until 1989 Dr. Kahaner was a group leader in the Center for Computing and Applied Mathematics at the National Institute of Standards and Technology, formerly the National Bureau of Standards. He was responsible for scientific software development on both large and small computers. From 1968 until 1979 he was in the Computing Division at Los Alamos National Laboratory. Dr. Kahaner is the author of two books and more than 50 research papers. He also edits a column on scientific applications of computers for the Society of Industrial and Applied Mathematics. His major research interests are in the development of algorithms and associated software. His programs for solution of differential equations, evaluation of integrals, random numbers, and others are used worldwide in many scientific computing laboratories. Dr. Kahaner's electronic mail address is: kahaner@xroads.cc.u-tokyo.ac.jp.

NIPPON STEEL KIMITSU WORKS

A visit to Nippon Steel's Kimitsu Works is described.

by David K. Kahaner

INTRODUCTION (STEEL)

In 1989, world steel production of about 780,000 thousand tons was divided as follows (in thousands of tons):

| | |
|--------------------------------|---------|
| U.S.S.R. | 160,000 |
| Japan | 108,000 |
| U.S.A | 88,000 |
| China | 61,000 |
| W. Germany | 41,000 |
| Italy | 25,000 |
| Brazil | 25,000 |
| Korea | 22,000 |
| France | 19,000 |
| Other (Canada, India, etc.) | 213,000 |

World steel production has been growing moderately. Growth among the top producers varies from a low of about 4% (Italy) to a high of 14% (Korea). U.S. production jumped 12% between 1987 and 1988 but decreased slightly between 1988 and 1989.

Japan consumes about 80% of its production, approximately half in the construction industry, 17% for automobiles, and 8% for industrial machinery. Although only a small amount of crude steel is imported to Japan, almost 100% of the iron ore and coal, the major raw materials used in steel making, is imported, primarily from Australia, Brazil, and India.

By comparison with other parts of Japanese industry, the steel industry is not exceptionally healthy. Nevertheless, a company like Nippon Steel is

huge, with nearly half a million employees, almost 300 subsidiary corporations, and an annual budget greater than that of many countries. Japanese steel exports are down because of production from other industrializing countries such as Korea. But a robust economy is allowing total production to grow. There is increasing concern about a lack of workers, both because of a general labor shortage caused by peaking/declining population and a resistance by young people to go into industries that are seen as dirty and dangerous. The industry recognizes that it must diversify into other businesses at the same time that it further automates steel making. For Nippon Steel, new fields are associated with building computers and software, new materials, and mobile communications. My own interest in Nippon's Kimitsu Works was primarily to see how far some of this automation had gone and to what extent computerization had been accomplished.

By company, steel production (in thousands of tons) in 1989 was as follows:

| | |
|------------------------|--------|
| Nippon Steel, Japan | 28,000 |
| Usinor Sacilor, France | 23,000 |
| Pohang, Korea | 15,500 |
| British Steel, U.K. | 14,200 |
| USX, U.S. | 12,900 |
| NKK, Japan | 12,300 |
| Thyssen, W. Germany | 11,900 |
| ILVA, Italy | 11,400 |
| Bethlehem Steel, U.S. | 11,000 |
| Kawasaki Steel, Japan | 11,000 |

NIPPON STEEL KIMITSU PLANT

The Kimitsu plant is due south of Tokyo (about 75 minutes by fast train), across Tokyo Bay in Chiba prefecture, and facing across the bay toward the industrialized cities of Yokohama and Kawasaki. It occupies 10 million square meters of flat, partially reclaimed land. There are about 13,000 people at the facility; less than half are Nippon Steel employees, and the others are contractors. In fact, Nippon employment at the site has been decreasing since the mid 1970s. Steel production at the site was mildly decreasing until 1988, at which time it took a large jump due to consolidation of other facilities. The fact that the company produces more steel at Kimitsu now than it did at its peak in the 1970s, but with about 15% fewer people, suggests that their automation procedures have been working. Employee attrition has meant that hiring has not been a problem, and that the plant has ample applicants for the few hundred positions that it has each year. (Mandatory retirement, except for the most senior positions, is at 60 years of age.) On the other hand, we were also told that applicants are not as good as they once were, presumably because more Japanese students are going to college, and hence the average ability level is going down. There are almost no Ph.D. hires. Nippon/Kimitsu, like many Japanese companies, prefers to hire younger scientists and train them in the specific skills needed in their organization.

Kimitsu is the largest of Nippon Steel's plants, producing almost 10 million tons of steel each year. Nevertheless, the key to making it economically successful is to use enough automation so that much smaller customized orders can be economically produced. This was emphasized to me repeatedly during my visit. For example, each slab from the furnace can be associated with a different order and has individual specifications and destination. This philosophy is consistent with some of my earlier reports (see the Scientific Information Brief on robots on page 4) about Japanese industry.

No steel plant is really clean. This one was probably much better than most. There are many new buildings, but some were clearly part of the original plant, now 25 years old. A modern research and development (R&D) center (1989) is within the plant site and undertakes research closely related to the production line (this was not part of our visit). In addition, just outside the present plant, three large R&D laboratories that are currently in other parts of Japan will be brought together into a brand new Research and Engineering Center of about one million square meters with 1,200 scientists. Topics to be studied include artificial intelligence (AI), fuzzy logic, robotics, and virtual reality. The Kimitsu plant sends about 100 engineers and scientists overseas each year, and about 1,000 trainees per year from various countries are invited to Kimitsu. With respect to international cooperation, for example from the United States, we were told that very few basic scientists are invited, and all of these are from industry.

I'm no expert on any aspect of steel making. However, with me on this visit were Dr. Iqbal Ahmad (Army Research Office, Tokyo), a materials specialist who understands steel technology, and three representatives of the commercial section of the U.S. Embassy, who

were able to explain many of the economic details. The Nippon Steel host was

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Our visit was coordinated by

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The basic steel making process is simple in principle and exquisitely complex in execution and detail. Iron ore, coal, and limestone are dumped in layers into a furnace (blast furnace) and melted. The molten "pig iron" goes to another furnace (basic oxygen furnace) where oxygen is injected in order to burn out and adjust the carbon content. Molten steel then goes to be cast (formed) into long rectangular slabs or long blooms (square cross section). Slabs eventually become flat products such as sheets, coils, pipes, or tubes, while blooms will become flanged beams, bars, and other sections. The trick is to do this quickly, efficiently, and safely, while at the same time maintaining consistency and quality in products with many different chemical and structural properties.

The blast furnace (one of three) we saw at Kimitsu has an internal volume of over 5,000 m³ and runs continuously for about 10 years, after which it is shut down and repaired. (It is currently in

the second year of its second cycle.) Molten pig iron is tapped eight times each day and then the hot metal is transferred to special rail cars for delivery to the oxygen furnace, which is in another building. Today's newest plants move these two closer together, even into the same facility. At Kimitsu, once the molten metal gets to the oxygen furnace, the remainder of the casting operation is continuous, with the steel moving through one of the longest buildings that I have ever seen. Red hot slabs go in one end, and coils, sheets, and other things come out the other, all still so hot they can't be touched. The entire facility has remarkably few people in attendance and appears to be thoroughly automated. Slabs weighing up to 45 tons each can be processed. These can be formed into very long coils, or left as plates that can be individually formed to any length between 3 and 25 meters.

KIMITSU-COMPUTING

My own interest in the blast furnace was associated with some AI techniques that are used to control it. After 25 years of steel making experience at Kimitsu, about 1,200 "If-then" rules have been developed (knowledge base) and integrated into an expert system, called ALIS, that monitors and adjusts various parameters associated with the furnace. The real time inputs to this are from 1,000 sensors. The system was written in-house, in C, and has a completely parallel maintenance system, so that new rules can be added or old ones modified by the operational staff. I think that this is fairly unusual in such a large system. Of course, I was not shown any of the actual code, which is proprietary, only some displays pictorially representing the blast furnace and its operation. In the control room I asked about fuzzy reasoning. The interesting aspect here was that the blast furnace supervisor was very well aware of what

this was all about and we talked for a while about the use of fuzzy membership functions. He explained that these had not been implemented yet, but that the software department was studying the possibilities.

There are essentially four main computer networks within the Kimitsu plant. The entire system has grown historically but is now mostly integrated.

- (1) A business system associated with the Kimitsu head office and other plants. Attached to this are various process-control computers with their own local area networks. There is also a node associated with communication, allowing contact with and location of vehicles within the plant and even further through a Yokohama relay station, as well as a 50-GHz radio transmitter allowing satellite access. There are almost 2,000 business terminals at the plant connected to this net. There are about 60 process control systems (primarily Hitachi HIDIC-80Ms, Mitsubishi MELCOM350/50s Fuji Electric FACOM s-3500s). These control everything from ordering of raw materials, through the various mills, transportation, and environmental control.

- (2) A phone and fax network (200 Mbps) connecting about 2,500 units.

- (3) A video data network (32 Mbps) for TV cameras. This also includes a CODEC (coder/decoder) allowing video conferencing. There are two video conferencing systems and two static video data transmission systems.

- (4) An image data network (100 Mbps) connecting 3 autochanging optical disk systems and 11 display

terminals. We were told that all of this was hooked together by optical cable through a digital PBX.

The Nippon Steel head office has two IBM 3090s (400E and 600E) and two Hitachi M-680Hs. These are also connected into the Kimitsu system and available for use there. Ohji told us that the Kimitsu plant was the first of such a large size to have such an integrated computing system. Once the customer places an order with the head office, processing of the order, material planning, production scheduling, production control, process control, production, and delivery are integrated into one system. We only spent about half an hour in the control room of the continuous casting mill and it certainly seemed that the operators were completely aware of where all the orders were coming from and going to, as well as order plans for the future. Ohji also gave us several detailed diagrams of the overall system organization, networks, and the process control system in the Hot Strip Mill.

I asked about software (SW) and was given the following statistics (in number of lines):

Business related computing

Application SW (COBOL)

| | |
|--------------------|------------|
| Production control | 13,000,000 |
|--------------------|------------|

| | |
|------------------------|-----------|
| General administration | 2,000,000 |
|------------------------|-----------|

| | |
|------------|-----------|
| Control SW | 1,000,000 |
|------------|-----------|

Process related computing

| | |
|--------------------------|-----------|
| Application SW (FORTRAN) | 5,600,000 |
|--------------------------|-----------|

| | |
|--------------------------|-----------|
| Control SW (Assembly, C) | 2,600,000 |
|--------------------------|-----------|

With respect to the application software, which is mostly in FORTRAN, I was told that this is written at the rate of about 1,000,000 lines per year, by about 140 people who average about 1,300 lines per month. This seemed pretty high to me and I asked about it.

Apparently maintenance is still a significant problem here, too. I guess that dusty decks are not only limited to the United States. All together, the computer system department at Kimitsu has almost 300 employees. About 80 of these are computer-control activities. Because we never got to meet any of the software staff, there was no opportunity to discuss the kind of modelling or other computing techniques that they employ.

While there were a great many terminals around, the color graphics terminals that I saw were mostly older IBM models and not very bright. There were a number of fairly good large screen projection systems, used mostly in control rooms for centralized displays. I also saw a few newer workstations in one of the control rooms, but was told that these were off line and being used to create an annual report. We did not get to visit the software section and so I do not know about the type of equipment they are using.

During the summing up session, Ahmad asked about accelerated quenching, a process that is of direct interest to the Navy. We were not shown any examples of this during our visit, but were assured that the process is in use within the plant.

NIPPON WORKSTATIONS

Our guide from Tokyo to Kimitsu was

Mr. Kenji Osasa
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Systems Division
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Osasa is in charge of planning information systems for Nippon Steel and is not involved in steel making. We had several hours of interesting discussions about two of Nippon's computer activities. Osasa explained that Nippon is an OEM supplier of various Sun workstations. I wondered why there should be yet another nameplate for sale here, but he assured me that they were hoping to compete on price and also to develop a number of specialized Japanese software products. Some justification is described below. He also mentioned that they were marketing a "PC" in the United States under the name Librex, currently as a 286 but soon as a 386 and 486. I really couldn't understand why they would want to inject another clone into this market. He agreed that it would be very difficult, but given that the market was so huge, such a high risk venture was worth trying.

In Japan as in the United States, workstations [engineering workstations (EWS)] are a rapidly growing item. Even though they are still far less common here than in the West, sales figures are still impressive. Estimates for unit sales in Japan are as follows.

| <u>Year</u> | <u>No. of Units</u> |
|-------------|---------------------|
| 1990 | 104,000 |
| 1991 | 147,000 |
| 1992 | 190,000 |
| 1993 | 262,000 |
| 1994 | 332,000 |
| 1995 | 429,000 |
| 1996 | 471,000 |

Japan represents between 25% and 33% of the world EWS market. For comparison, IBM and Fujitsu each have an installed base of around 5,000

mainframes in Japan. Of course, workstations are much less costly than mainframes, but the cost of buying/leasing software for them is not so different and represents a tremendous potential market.

In 1990 Sun had about 30% of the EWS market, Hewlett-Packard 15%, and IBM about 11%. These percentages seem to be growing, while Sony has about 25% of the market and its fraction seems to be shrinking.

Between 1986 and 1990 packaged software, as opposed to customized software, accounted for 30% to 40% of U.S. software sales; in Japan the corresponding figure is only about 7%.

Thus it would seem that there is a good opportunity to sell Sun workstations with high profit proprietary software in Japan.

THE FIRST INTERNATIONAL WORKSHOP ON ALGORITHMIC LEARNING THEORY

The First International Workshop on Algorithmic Learning Theory (ALT '90) took place in Tokyo on 8-10 October 1990 and was attended by 120 researchers. This report summarizes the major papers discussed there.

by David K. Kahaner and David Haussler

INTRODUCTION

Algorithmic learning theory is the theoretical portion of artificial intelligence (AI) that is concerned with machine learning.

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was invited to participate in the international workshop held recently in Tokyo. His detailed summary is given below. Interestingly, the paper that Haussler felt was the best in the workshop, by S. Amari, is similar to another of Amari's that I was very impressed with earlier [see D.K. Kahaner, W.J. Freeman, and A.F. da Rocha, "Fuzzy logic," *Scientific Information Bulletin* 16(1), 41-47 (1991)]. Amari was also the organizing chair of the New Information Processing Technologies Workshop held in December 1990 (see my article on this workshop on page 31).

WORKSHOP SUMMARY

The First International Workshop on Algorithmic Learning Theory (ALT '90) took place in Tokyo on 8-10 October 1990. The workshop was sponsored by the Japanese Society

for Artificial Intelligence, with cooperation from the Association for Computing Machinery's (ACM) SIGACT and SIGART groups, the IEEE Computer Society, the Information Processing Society of Japan, the Institute for New Generation Computer Technology (ICOT), and many other organizations, and with financial support from 12 Japanese corporations and foundations, including Fujitsu, Hitachi, IBM Japan, Mitsubishi, NEC, NTT, and Toshiba. It is anticipated that the meeting will be held every other year in the future. This year approximately 120 researchers from all over the world attended the meeting.

The term "algorithmic learning theory" is similar to the term "computational learning theory" used for the annual workshops on this subject held in the United States (the COLT workshops). So far there have been three COLT workshops (MIT '88, UC Santa Cruz '89, and Rochester '90), sponsored by ACM SIGACT and SIGART groups and originally funded in part by grants from the Office of Naval Research (ONR) and the National Science Foundation (NSF). ONR may also help fund a fourth COLT workshop, to be held 5-7 August 1991, again at UC Santa Cruz. The field of algorithmic/computational learning theory has its roots primarily in artificial intelligence work in machine learning, including work in statistical pattern recognition

and classification in the early 1960s and the recent work on learning in neural networks, and in E.M. Gold's work on inductive inference of formal languages. Computational learning theory, as practiced by the researchers that attend the ALT and COLT meetings, represents a major theoretical component of AI learning work.

Within computational learning theory there are three major established lines of research and a number of newer alternative approaches and ideas. These approaches were all represented at the ALT meeting. The oldest line of investigation is often called inductive inference or learning in the limit. The papers of M. Fulk and S. Jain, K. Jantke, J. Case et al., S. Lange and R. Wiehagen, P. Garcia et al., T. Shinohara, and A. Togashi and S. Noguchi at ALT present new results in this line of research.

The inductive inference approach grew out of recursive function and computability theory and is still dominated by methods from these fields. To illustrate the type of problem considered in inductive inference work, consider the problem of designing an inference machine to learn a language in the manner that a child learns, i.e., not by being told what the grammar of the language is but rather by hearing grammatical sentences. In an abstract sense we can view grammatical sentences in the natural language as finite strings of

symbols over a finite formal alphabet (here the formal alphabet is actually the set of words in the natural language.) The (usually infinite) set of strings over this formal alphabet that corresponds to possible sentences in the natural language constitutes a formal language.

The inference machine must learn which of the infinitely many possible strings of symbols over the formal alphabet are in the formal language and which strings are not. The only information available is a sequence of examples. In the simplest case, each example is simply a string in the formal language. In the more general case, there are two types of examples, strings that are in the language (positive examples) and strings that are not (negative examples). In either case, it is assumed that the sequence of examples given to the inference machine includes all possible examples. The inference machine is successful in learning the language if no matter what order these examples are presented in, sometime during the presentation the machine makes the correct hypothesis and stays with this hypothesis from that point on. Here the hypothesis is some correct representation, perhaps a grammar, for the formal language that is being learned. It is said that the machine is able to learn an entire class of formal languages if it is always successful on each language in this class. The same setup can be used to investigate inference machines that are able to learn classes of subsets of the integers, or indeed classes of functions on arbitrary countable domains. (A formal language can be viewed as a function on the set of all strings that takes the value 1 on strings in the language and 0 on strings not in the language.)

This approach has been called learning in the limit because there is no constraint placed on the number of examples needed before the correct hypothesis is discovered. It only has to happen sometime "in the limit." Neither is any constraint placed on the computational complexity (e.g., time complexity) of the procedures used by the inference machine; they need only be computable. This has made results from this model of limited use in practice. The two other established lines of research in computational learning theory attempt to remedy this situation. One of these is called exact identification in polynomial time. Here the inference machine (or learning algorithm as it is usually called) is allowed to make queries about specific examples and hypotheses of its own choosing. Further, the learning algorithm is required to terminate after making only polynomially many such queries and to use only polynomially bounded computation time. These polynomials are defined in terms of the complexity of the function that is being learned (called the target function). This represents a more "active" approach to learning, as well as being more practical when it comes to actual implementation. Many papers at ALT '90 presented new results in this line of research, including the papers of N. Abe, S. Lange and R. Wiehagen, Y. Takada, and Y. Takada et al.

The third established approach in computational learning theory is the probably approximately correct (PAC) model. Here examples are presented randomly to the learning algorithm, and the algorithm is not required to learn the target function exactly, but only to find a hypothesis that is a good approximation of it with high probability. A good approximation means a

hypothesis that gives the same value as the target function on most randomly drawn examples. Of course, these definitions depend on the probability distribution that is used to generate examples. Usually, it is assumed that when the target function is f , examples are generated by drawing instances from the domain of f independently at random according to some arbitrary distribution and then labeling each instance x with the value $f(x)$. Thus the learning algorithm receives a training sample $(x_1, f(x_1)), \dots, (x_m, f(x_m))$, where the x_i 's are drawn independently at random and must produce a hypothesis that is a good approximation of f (with high probability). The learning algorithm is required to work for any distribution that may be used to generate the instances x_1, \dots, x_m in the training sample. Moreover, it is required that the number m of examples and the computation time be polynomial in the complexity of the target function, as in the model of exact identification in polynomial time.

The PAC model is often applied to the problem of designing and analyzing algorithms that learn Boolean functions, although it can also be used when more general classes of functions are needed. The model incorporates some of the perspective of statistical decision theory into the framework of inductive inference, as well as adding computational complexity considerations. Of the three established lines of research in computational learning theory, the PAC model has gained the most attention by practitioners of machine learning. However, many practitioners have been unsatisfied with the model. One reason is that not enough of statistical decision theory was incorporated in the model. In particular, the model was originally defined only for learning

functions that take two values, and it was assumed that there was no noise in the training examples. Since then various noise models have been added (see the paper of Y. Sakakibara), but only recently was the model generalized to cover the important problems of regression and density estimation, as well as function approximation. These generalizations were described in my paper at ALT, and in part in N. Cesa-Bianchi's paper. A decision theory approach to learning was also described in the excellent paper of S. Amari, entitled "Mathematical Theory of Neural Learning." This paper analyzes the dynamics of learning in neural networks, providing a beautiful and rich perspective. It is, in my opinion, the most important paper presented at ALT '90.

In addition to other work on neural networks (in the papers of N. Namatame and R. Oka), and extensions or relatives of PAC learning (papers of J. Kivinen, and A. Shinohara and S. Miyano), a number of other approaches to machine learning, beyond the three established lines of work discussed above, were discussed at ALT. These include learning and reasoning by analogy (papers of B. Shekar et al.,

T. Unemi, M. Harao, J. Arima, B. Indurkha, and R. Orihara et al.), important new work on learning methods in logic programming (papers of S. Muggleton, S. Muggleton and C. Feng, M. Hagiya, and S. Liu and M. Hagiya), and formal work on explanation-based generalization (papers of P. Laird and E. Gamble, and T. Tanaka). This great variety of work kept the meeting lively and the discussions animated.

CONCLUDING REMARKS

Overall, I would say that the meeting was very successful. I believe that the field of computational learning theory is still in the process of searching for the right foundation, and that none of the frameworks proposed so far are nearly adequate. I see the great variety of new formal models of learning that are being proposed as a healthy sign. The worst thing that could happen now would be to have the field ossify into one of the three established and inadequate lines of research discussed above. As most of my work has been in the PAC model, it is perhaps no surprise that I feel that of the three models,

this model provides the best starting point from which to consider modified theories that will enrich our ability to formally capture the learning process. I believe also that much of the impetus for these revisions in computational learning theory will come from the important applied learning work that is currently being done in the field of neural networks. This fabulously rich, interdisciplinary field may very quickly change our fundamental notions about the learning process. It will pay us to monitor it carefully.

David Haussler is an Associate Professor of Computer and Information Sciences at the University of California at Santa Cruz. He received his master's degree in applied mathematics from California Polytechnic State University in 1979 and his Ph.D. in computer science from the University of Colorado in 1982. Prof. Haussler's current research interests are in machine learning, neural networks, text processing, computational geometry, theory of computation, and computer applications in biology.

COMPUTING IN TAIWAN

Computing in Taiwan is discussed by describing two meetings at National Tsing Hua University (Taiwan), the International Computer Symposium and the First Workshop on Parallel Processing, as well as a visit to the Institute for Information Industry (Taipei).

by David K. Kahaner

OVERVIEW

The International Computer Symposium, essentially Taiwan's Information Processing Society meeting, was held for 3 days, 17-19 December 1990, at National Tsing Hua University, in Hsinchu, about 70 km south of Taipei. All presentations and papers were given in English. There were approximately 400 participants; about 160 papers were presented out of almost 400 submitted. This was immediately followed by a 2-day Workshop on Parallel Processing, at which all the presentations were in Chinese. The workshop had over 200 participants. Both meetings have printed Proceedings in English. I have one copy of the Proceedings and will send copies of papers to requestors if I have the time. Additional copies can be obtained by writing

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After the meetings I spent 1 day in Taipei, at the Institute for Information Industry.

There were only two or three Western scientists in attendance at the International Symposium and none at the Parallel Processing Workshop. Most of the participants from outside Taiwan

were Taiwanese from the United States, or Japanese, or other Chinese speaking scientists from Hong Kong or Singapore. I saw no evidence of attendees from mainland China, Korea, or other Pacific Rim countries. Generally the best papers were from outside Taiwan, although most of these were by Taiwan-born scientists now living in the West. I did not see much evidence that these scientists are moving back to Taiwan into senior positions. My general impression, confirmed by most of the Chinese-speaking attendees, and by all the non-Taiwanese, is that Taiwanese computer research activities are heavily theoretical. This reflects the fact that presently there are few practical parallel processing projects in the country. (I was told that there are a few computer systems oriented, experimental research projects in Taiwan, but that they are behind in all practical areas, not just in practical parallel processing. I did not get to see any of these.) In that sense Taiwanese research is behind Korea, where a reasonable amount of catch-up research is in progress. However, a few theoretical papers were very good, although the best was by two Hong Kong computer scientists on mapping of a two-dimensional mesh efficiently onto a hypercube. A handful of numerical computation papers were presented, but this seems a particularly weak area.

GENERAL BACKGROUND

About 2 hours flying time southwest of Tokyo, Taiwan straddles the Tropic of Cancer (as does Hawaii). It has about 2.5% of the land mass of mainland China and a roughly proportionate population (20 million). The country is densely populated and rugged, with only one-third arable land and more than 60 over-3,000-meter peaks. Taiwan is the original name of the island; Formosa was a Portuguese word meaning beautiful island, used until recent years. The present Government considers Taiwan part of China (hence ROC=Republic of China), although many of the scientists I spoke to did not share that view. Restrictions on Taiwanese trips to the mainland have been reduced in the past few years and several hundred thousand have visited. The present Taiwanese Government still has many tough sounding laws developed in an era when relations between the mainland and them were very tense, although I was told these are being relaxed. Nevertheless, there is plenty of controversy; on TV I was astonished to see a free-for-all fight in the "parliament." Political issues (of which I have no knowledge) aside, if Taiwan and mainland China can resolve their differences, China will be a huge natural market for Taiwanese products and expertise.

Taipei, the capital, has about 2.5 million people. It is choked with traffic and heavily polluted. There is no metro, although one is being built. This is surprising, as Taiwan's per capita income is over \$8K, about 50% more than that in Korea, which has a substantial metro system in Seoul. (Viewing Seoul and Taipei, I was not able to distinguish differences in the income levels of these countries. My Korean friends tell me that the differences are noticeable in the countryside.) Nevertheless, it is easy to find one's way, as most streets are on a rectangular grid.

Hsinchu, the site of both meetings, is also the location of Taiwan's largest science-based industrial park, established in 1988. There are already over 100 manufacturers, close to 20,000 people, and more than 100 Ph.D.s working in the park. Unfortunately, as most of the computer-types were at these meetings, there was no opportunity to visit any of their laboratories. This would be an important stop on any subsequent trip. Hsinchu is also the location of two major universities, National Tsing Hua (with about 4,500 students and about 450 faculty) and National Chiao-Tung. The model for growth here seems to be Tsukuba Science City in Japan.

COMPUTING IN TAIWAN

More than 5,000 companies (about 90,000 people) are engaged in either manufacturing computer-related hardware or exporting it out of Taiwan. Taiwan makes about 60% of the world's PC motherboards. However, until very recently, they did not make complete systems. This has now changed. I tried several perfectly reasonable all-Taiwanese PCs, including several 386s. Some of these are beginning to be exported. I was told that Taiwan products now satisfy almost all internal PC demand. However, many of the best use Japanese monitors. I was also told that in the near future there will be a

Taiwanese Unix-based workstation, for internal use. Almost all systems larger than PCs had been imported until recently, and the Government has identified that as a major area for growth. There are also some strange properties of the Taiwan market. For example, until very recently, there were more Wang systems installed than IBMs.

An important part of computer growth in Taiwan is associated with the ability to input Chinese characters. This is a significant research activity both here and on the mainland. (Japanese is spoken by many older Taiwanese, as a result of the Japanese occupation of Taiwan during the first third of this century.) There is also a good deal of manufacturing for Japanese products; my Sony Walkman has cables clearly marked "made in Taiwan." During this trip I only was able to talk to academic computer scientists, but I was repeatedly told that the best Taiwanese technology is associated with manufacturing. Apparently this is true. Industrial growth has averaged over 13% per year for more than 30 years, more than 50% of the country's GNP is now generated through exports, and Taiwan is the second largest holder of U.S. dollars (after Japan). Computer industry growth has also been very good; the only items now growing are printers and terminals. By 1995 research expenditures are projected to be about 2% of GNP, with 0.2% of the population designated as "researcher." For research in the information and electronics industries, 3% of researchers have Ph.D., 48% have M.S., and 40% have B.S. degrees.

There are many Government-sponsored programs; discussing these in detail would require a separate report. The National Supercomputer Center (see below), Sub-Micron Parts Laboratory, and the Hsinchu Science Park are among the most recent and interesting.

The ROC Government has various plans for making computers even more important in Taiwan's economy. Some

are general, and other are quite specific. For example, they have identified 14 specific manufactured items that they want to promote:

- Cathode ray tube (CRT) monitors
- Low-speed nonimpact printers
- Low-speed impact printers
- Medium speed printers
- Linear scanners
- Fixed (hard) disk drives
- Optical readers
- Chinese-English word processors
- Micro and minicomputer systems with Chinese operating systems
- Software for medium and small computers
- Modems
- Chinese language electrical typewriters
- Floppy disk drives
- Computer magnetic tapes

An interesting area worth following is the Taiwanese development of systems larger than PCs. Already, with licenses from SUN, a workstation consortium has been developing a SPARC-compatible system. About 2 years ago an experimental 32-bit RISC multiprocessor machine (called MR-10), running Unix, X-Windows, and suitable as a network file server, was introduced. This was done by the Industrial Technology Research Institute (ITRI) under the sponsorship of the Ministry of Economic Affairs. I was told that the spinoffs from this project will be several special purpose machines, such

as a database server, and more interestingly a vector processor, but I had no opportunity to learn about this in more detail. It seems that with possibly the exception of the SPARC-compatible workstations, all these projects are for acquiring basic computer technologies rather than for immediate commercial use.

PAPERS OF INTEREST

The International Computer Symposium was organized into 1 day of tutorials followed by 2 days of four or five parallel sessions, each containing an invited presentation, and three or four submitted papers. With one exception, the tutorials were all by Chinese now working in the United States, as were many of the invited papers. The Parallel Processing Workshop consisted of only one track, but as mentioned above, all the talks were given in Chinese. Some of these were by speakers from the symposium, presenting some new results, but also several overview papers, such as the one by Fang (Convex) on automatic parallelization techniques, or by C. Hsiung (Cray) on how supercomputers are going to fit into future computing systems. I concentrated on papers from non-Western scientists on the theory that others' work is already fairly well known. Ultimately, only three that were most interesting to me are reported here. (At any meeting with parallel sessions it is easy to overlook outstanding papers.)

Optimal Mesh to Hypercube Mapping

The best technical paper was by

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James Capel (Far East) Ltd.
Hong Kong

and

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The problem the authors consider is extremely important. We are given a two-dimensional mesh and a hypercube computer. The mesh might come from a finite element calculation. A hypercube is a collection of individual computing processors (elements) that are connected in a very special way, so that the individual elements are thought of as at the vertices of a multidimensional cube. A 3-hypercube contains 2^3 elements, a 5-hypercube contains 32 elements at the vertices of a 5-cube, etc. Hypercubes were the first commercially practical parallel computer; many systems are in use, and there is a tremendous amount of research on effective algorithms to take advantage of their structure. For a two-dimensional finite element mesh, it is natural to associate each mesh point with a processing element of the hypercube. But how, specifically, should this association be made? For example, how should we associate 9×3 grid with 27 elements in a 5-hypercube (32 elements)? Of course, any association will work, but an efficient one will recognize that neighbors on the grid should correspond to neighboring processors in the hypercube. The reason is that the only way two hypercube processors can communicate is along the edges of the cube. For a 3-cube this can mean that a message might need to pass through two intermediate processors to get between sender and receiver (along three edges); a 5-hypercube may require passage along five edges.

This problem had already been studied by the present authors, as well as others, and Chan had provided an

algorithm for doing this in an optimal way, in the process proving that it was always possible to arrange the association so that adjacent neighbors on the grid are separated by at most one intermediate processor. But that algorithm for deciding how to do this is slow and suffers from some other difficulties. The current paper describes a parallel algorithm associating any two-dimensional grid to its optimal hypercube. The size of the grid is broadcast to each node of the hypercube, which can then determine in constant time which grid node it will associate with. Moreover, each node can also determine the communication paths it will take to reach the nodes associated with grid neighbors. Further, each node will act as an intermediate node for at most two pairs of grid neighbors, reducing potential congestion at intermediate processors. This is a very excellent theoretical result that has substantial practical implications. The authors claim that they can extend the method to three-dimensional meshes. Part of this work was sponsored by an Office of Naval Research (ONR) grant while Chin was at the University of Texas, Dallas, making it even more satisfying for me to report.

Keynote Speech on Science, Technology, and Industry

The keynote speech of the symposium was by Hitoshi Watanabe, vice president, NEC Corp. Watanabe explained that he had invented NEC's first computer. This had 48-bit floating point arithmetic and some parallel architecture, although his original design called for 64-bit floating point. He showed us a photo of a much younger man standing in front of a very large console that is now in NEC's museum; the console was the only part that would fit. The essence of his talk was his view that science (theory), technology (design), and industry must be an

indivisible activity, what he called STI activity. He called STI a chain from fundamental research, applied research, development, production, to sales and marketing that must be balanced at each link, and that the mission of engineers is to consider all these parts at the same time. He went on to illustrate this by various examples. For instance, in the 1910s theory consisted of Boolean algebra, Kirchhoff's topological rules, etc.; design was typified by research in loaded lines; and industry centered in electric power systems and telephony. He went on to illustrate the point during the 1920s to 1950s and then 1960 to the present. He also showed "maps" of the information industry at various periods. Frankly, I didn't get much out of these slides except that integration is here to stay. The slides were reproduced as part of the symposium materials, but his lecture itself was not available in printed form, and many interesting details were given, rapid fire. Unfortunately, Watanabe did not stay around long enough to allow me to corroborate my notes. The most sensible of these are given below.

Watanabe described the workstation of the near future (2000) as having a 5.25-inch read/write video disk, a flat panel color display with 10 million pixel resolution, connected by optical fiber (by 2010 all fiber optic) to a broadband intelligent network. Communication will be by either asynchronous or synchronous transmission mode. He said that executives don't like to use keyboards, so the workstation will have a touch screen, mouse, or more sophisticated input. He showed an artist's sketch of a Japanese office with these workstations, screens neatly integrated into office furniture and a small server tucked away elsewhere. He emphasized flat panel technology repeatedly to display color and high definition television displays

mounted on the wall, with scenes changed under computer control. (In the 1960s Richard Hamming made similar predictions, but the technology had not been invented at the time.) Integration and globalization were key themes. One interesting comment was that NEC was definitely using its supercomputing technology downstream. Watanabe explained that the "same" high performance LSI technology used in NEC's SX-3 was also being used in its water-cooled 3800/20 and 3800/60 mainframes. While this is no surprise, it reinforces the economic justification for expensive research and development (R&D) used in small unit sales products. Of course, until this year NEC has not sold many of its SX computers.

He ended his talk with a very general description of several important future research directions.

| | |
|-------------------|---|
| Future Industry: | Integrated Information Networks |
| Basic Theory: | Unified modeling theory for information networks |
| Practical Method: | Efficient method of information network integration |
| Final Target: | Useful network compiler for large scale network (several hundred thousand subparts) |
| Future Industry: | Global Systems |
| Basic Theory: | Elegant modeling theory for social systems |
| Practical Method: | High performance simulation |
| Final Target: | Powerful simulator for complex global systems |

This was a perfect presentation to inspire the scientists and students at this meeting, but there was no opportunity to dig out some of the most important details.

After Watanabe's lecture,

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who was another of the invited speakers, commented that if we really wanted to see integrated computing and communications we should visit his laboratory in Berlin.

Testing Vectorized Fast Fourier Transforms

One of the most heavily used algorithms is fast Fourier transform (FFT). In fact, it has been called the most important computer algorithm ever devised and plays a key role in a vast number of applications, from solving partial differential equations to image processing. Although the first significant paper was in 1965, research continues even today. Every computer vendor that markets to scientific users provides a highly optimized collection of FFT routines.

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reported on his studies of several variations of the FFT, with special emphasis on their implementation for large general purpose supercomputers. One

of the least well known, Ruritanian's method, performed best when Chung timed it on a Convex C-1. Unfortunately, Chung used his own implementations of these algorithms rather than tuned implementations provided by vendors, or even carefully coded ones in the public domain such as by Schwarztrauber, etc. With the dearth of work in Taiwan in numerical computation, it is a pity that when someone wants to do something he is hampered by lack of access. In this case Chung would benefit very greatly by having access either to source programs of good FFT implementations or at least an opportunity to run his programs against some of them. Western researchers who are interested in this topic should write to Chung directly.

POSTMEETING DISCUSSIONS

R.C.T. Lee, National Tsing Hua University

I had a fascinating morning with Tsing Hua's Dean and University Provost,

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Lee was also general chairman of the International Symposium. Lee is a computer scientist who is still active. He gave me a list of about 50 publications, including several books. (One is to be published early next year.) He still supervises several Ph.D. students, and his office is filled with photos of former students in wedding poses and others with newborn children. Hsinchu as a city is clearly moving toward science,

and this emphasis is reflected in the university. Nevertheless, Lee is trying to expand literature and other liberal arts appreciation with special programs, exhibits, etc.

We talked for a while about problems in Taiwan with industry, especially relative to Korea. As mentioned earlier, Korea has much less per capita income than Taiwan, but Korea also has several very large companies, such as Daiwa, Pohang, etc. On the other hand, Taiwan has mostly small to medium sized companies. Lee remarked that there were advantages and disadvantages with either. Of course, large companies can have the resources needed for big time research, but they are often inflexible and slow to respond to changes. A Taiwanese scientist told a story about a friend who owned a company that manufactured electronic arcade games, but when the market for these slowed recently the company was able to change almost overnight, to producing PCs.

Lee felt that the ROC Government needs to be more proactive in helping industry. He told me about a new Government program that he had a hand in promoting that tries to do this. In it, scientists (from universities and research laboratories) come together to define some products that need to be developed, along with fairly detailed specifications. Subsequently, private industry makes proposals for the development work (which involves some technology transfer from the universities). Half of the development funds come from the Government and half directly from the winning company. Lee also mentioned another program that allows engineers and technicians from industry to spend a few weeks to a few months at a university being trained in some new technology, integrated circuits were specifically mentioned in this context. Workstations were another area where Taiwanese technicians

needed retraining. Until recently, there was a great deal of PC expertise but not much Unix development experience. When this was recognized, substantial numbers of Taiwanese were sent out of the country to learn the necessary skills.

Generally, though, Lee acknowledges that it will be impossible to compete directly with Japan at the cutting edge of high technology, and that Taiwan should focus on those areas for which it is best suited. In his opinion, small company manufacturing is done very well in Taiwan and definitely surpasses Taiwanese skills in computer systems. There are some anomalies, though. Taiwan has a strong trade surplus (these figures change yearly), but in the area of electrical components, including connectors, etc., the net flow is from Japan to Taiwan. Lee urged me to return and visit the industrial manufacturing facilities that he could arrange and also to meet the Minister of Economic Affairs, who he characterized as a scholarly and scientific person. Unfortunately, this trip was primarily to attend these conferences and for get-acquainted purposes.

Finally, I remarked to Prof. Lee that I was disappointed by the lack of papers about numerical computation at either of the meetings. He agreed that this was a serious problem; researchers here are not much interested in computer modeling. Of course, an important reason is the lack of general purpose high performance computers.

[There was one session at the symposium specifically designated for numerical computation. It promised to have one excellent invited talk on sparse linear systems by Prof. D.J. Evans (U.K.), who unfortunately was unable to attend at the last moment. Of the three remaining papers, one was by a physicist who had reinvented the method of lines and the other two by students. Attendance at this session was very low, reflecting the general interest in these topics among the attendees.]

K. Wu, National Supercomputer Center

The Government is hoping to increase research in numerical modeling by its development of a National Supercomputing Center.

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National Supercomputer Center
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is on leave from Cray Research to help establish the center. Wu told me that they had just received \$85M to be spent over 5 years. Half will be for equipment and half for a staff of about 100, including half researchers. A building is now being constructed in the Hsinchu Science Park. The center expects a machine to be delivered in 1992, essentially to provide supercomputer cycles to the academic community, a la the U.S. National Science Foundation (NSF) centers. No decision has been made on specific hardware, although their budget allows for a high-end system, such as a Cray Y/MP. Wu claims that they are looking to the future and so might be interested in an SSI. My own feeling is that, prestige aside, they will ultimately go for a mature system and let larger installations be test sites for new machines. At this stage of their activity, Wu and his staff are just beginning to search out potential users to learn more about their needs.

K. Kin, Convex Computer, Asia

I also had the opportunity to talk with

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Managing Director, Asia/Pacific
Operations
Convex Computer Pte Ltd.
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about supercomputer and minisuper applications. I began by asking why his office was in Singapore instead of Japan, where there are already more than 50 Convex systems installed. He explained that Convex does have an office there, but the company considers Japan a separate market from the remainder of the Pacific region. He felt that too many organizations centralize themselves in Japan, and then because of all the activity there have less incentive to consider other countries where individual potential may not be as large. For Convex, business has been brisk this year in Taiwan, Malaysia, India, etc. while many other American firms remain fixated on Japan—a mistake he felt. Of course, the Japanese are well aware of this and are actively going after this market, too. Kin claimed that he also had a substantial number of potential orders from (mainland) China but until recently had been prevented from accepting them because of export restrictions.

Having such a widespread customer base causes problems, too. A complete set of spare parts is stocked centrally, in Convex's case in Taiwan, and this needs to be restocked from the factory in the United States. Convex emphasizes the reliability of their equipment; nevertheless, there are a few engineers in the Singapore office who respond to problems. For some installations, such as the one in Sumatra (Indonesia), the contract called for an engineer on site. This has turned out to be a real hardship assignment, as the engineer has repeatedly been ill, including a bout with malaria. Kin himself is on the road most of the time. In fact, his family has remained in the Washington, DC, area, but he gets to see them about once a month.

Several of the scientists at the meeting agreed that a medium sized Convex was a good bet for departmental computing in many mid-sized companies or universities that could not justify a larger Cray-class machine. On the other hand, having a "real" Cray has advantages, too, not the least of which is its name recognition, especially with politically savvy government ministers or corporate board members. Sometimes this matters quite a lot.

I asked Kin if he could generalize about his user community. He explained that oil-related applications have been important recently because of concern about oil supplies from the Gulf. He also confirmed my own observations that outside of universities and some government institutes, almost all users are running packaged applications. Only within the university environment is any substantial programming being done. [Later, I was able to verify that in a recent survey of computer languages being used, within Taiwanese Government agencies Fortran is almost as popular as Cobol, twice as heavily used as Assembly, and three times as heavily used as C.] Also, like Cray, Convex is concerned about distributed memory parallel processing. Their conventional wisdom is that a reasonable model for many new installations will be to provide a parallel processor as a node on a heterogeneous multicomputer network.

Finally, I mentioned to Kin my conversations with NEC's SX-3 designer Watanabe, who claimed NEC was not interested (at this time) in marketing a minisuper machine. Needless to say, he was very happy to hear this.

As far as Convex's current software activities are concerned, an excellent survey of automatic parallelization techniques was given by

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Fang thought that Convex had every reason to hope that its Fortran compiler would shortly be better than Cray's at automatically finding and taking advantage of parallelizing opportunities, primarily because Convex is developing their compiler from scratch rather than having to make it compatible with older products. Personally, I am skeptical.

INSTITUTE FOR INFORMATION INDUSTRY (III), TAIPEI

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Sec 2, Taipei, Taiwan, ROC
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This is a Government-financed organization focused on promoting information technology in Taiwan and planning its growth. It was founded in 1979 and currently has about 650 employees in half a dozen locations within Taipei. It also has two exhibition centers in the United States, one in Mountain View, CA, and a second in Gaithersburg, MD (about 5 minutes from my U.S. home). I spent 1 day at the III main office but unfortunately did not get to meet any of the higher level or research staff. It would be useful to return in order to get a better picture.

In addition to promotional and planning, III has several products or services that their staff has developed. Many of these are very closely related to corresponding items in the West but

have been fully absorbed by III's staff to the point where new design and implementation can be done locally. The most important of these is the Software Engineering Environment Development (SEED) project. Begun in 1989, it is hoped that this will create a good distributed software environment via integrated networks, all the related information, methods, standards, and tools needed for software development. The idea is to have as many of Taiwan's software development projects working under SEED in order to improve productivity and reliability by using a standard environment. More specifically, SEED will build workstations and provide communication, an operating system (Unix kernel, CHINEX), graphics window interface, database system, and mail system. The mail system, workstation tools, Form Master, and Imagemaker are clearly derived from Western products but have been modified to deal with Chinese characters. There is also a Chinese Input System built around phonetic input, much like Japanese "kana" input systems. The SEED software/hardware is developed by III staff and also with support from several Taiwanese computer companies. III is also developing a SEED Service Center where various services, such as network management, databank, consulting, training, etc., are located. SEED has also published its second version of a handbook, *Software Development Guidelines*, to explain international software standards.

Other countries have also established programs with some of the same goals as SEED. In Asia these include SIGMA (Japan) and SUPER (Korea).

III has been involved in expert system research. This would not be considered at a terribly exciting level by most Western standards. Nevertheless, they have built rule-shell, frame-shell,

and Chinese-shell expert systems and have been applying prototypes to taxation auditing and auto malfunction reduction. All concerned now believe that more professional training needs to be done in order to get expert systems more firmly rooted in the country.

III also publishes several excellent survey reports with detailed statistics of computing technology in Taiwan. I can provide copies of these to a limited number of requestors.

SUMMARY

- The most interesting papers were from the West.
- Computer-related research in Taiwan seems much more theoretical than practical.
- The best paper, about optimal mapping of mesh onto hypercube (from the University of Hong Kong), had some ONR support.
- Numerical computation papers were almost nonexistent.
- NEC's vice president, Watanabe, describes his vision of Science, Technology, Industry as inseparable and claims that supercomputer technology will be used in NEC's mainframe machines.
- A National Supercomputer Center has just been established.
- Taiwanese industry is moving away from PCs.
- The Government has various plans for computer growth and research, including Hsinchu Science Park, the Institute for Information Industry, and special manufacturing focuses.

NEW INFORMATION PROCESSING TECHNOLOGY WORKSHOP

A 2-day workshop, 3-4 December 1990, was held in Hakone, Japan, to discuss aspects of a possible Japanese new 10-year program to follow the Fifth Generation Institute for New Generation Computer Technology (ICOT) program that is to end in 1992. A summary of the discussions is presented and some opinions about the directions that this program might take are given.

by David K. Kahaner

INTRODUCTION AND SUMMARY

Over the past year I have written several reports on long-term Japanese research programs in computing. The most famous of these programs is the "Fifth Generation" project, also known as the Institute for New Generation Computer Technology (ICOT) project. ICOT is scheduled to end in 1992 and the Japanese Government is studying possible follow-on projects. The most exciting of these, and the largest, is NIPT, or New Information Processing Technology. The name "Sixth Generation Project" is Western, not Japanese. I reported electronically on early plans for this [NIPT, 25 June 1990], listing the main goals of the project and names/affiliations of various committee members. It also gave some comparative information about projects in the United States and European Community (EC) that overlap [see also JAPGOVT.UPD, 30 July 1990]. In March 1990 the Ministry of International Trade and Industry (MITI) issued "Report of the Research Committee on the New Information Processing Technology," in English, describing the status and goals of the program. Both my 25 June 1990 report and MITI's should be considered as significant

appendices to this one. Please write to me for copies of either of these. (The MITI report is not available in electronic form.)

The overall goals of the program may have evolved slightly since those reports, or perhaps different people have been talking about them. Briefly, NIPT is to perform research and development of new paradigm information processing technologies based on "soft (flexible) information processing" and "integrated computing." The actual meanings of these terms are vague enough that a great deal can be subsumed under them. The program is proposed to have three major components:

1. Theoretical. To establish new theoretical foundations for soft information processing on integrated computing systems.
2. Technological. To develop integrated computing systems with new architectures, including artificial neural networks and optical computing systems, which are well suited to soft information processing.
3. Application. To create and expand application domains of soft information processing functions on integrated computing systems.

More detailed goals of the program have not been articulated and its targets are explicitly to be left flexible.

If this program goes forward as its proponents hope, it will be funded over 10 years at the level of \$30-40M per year, beginning in 1992.

The general Research Committee on New Information Processing Technologies draws upon three subcommittees, Fundamental Theory, Computer Science (CS), and Social Impact. The CS subcommittee is in turn broken into two collections of working groups. The overall organization of the NIPT Committee is as follows:

Fundamental Theory Subcommittee

Computer Science Subcommittee

Integrated Computing Working Groups

Theory and New Functions Subworking Group

Neural Systems Subworking Group

Massively Parallel Systems Subworking Group

Optical Computer and Devices Working Groups

Needs for Optical Computing Subworking Group

Parallel Optical Digital Computer Subworking Group

Optical Neural Computer Subworking Group

Optical Interconnection Subworking Group

Social Impact Subcommittee

Because of the intense international interest, and also to solicit new ideas as part of the planning process, the

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organized a workshop in Hakone, about a 1-hour train ride south of Tokyo, from 1-2 December 1990, to bring together the working groups and to discuss the new NIPT proposed program.

Invitations to the workshop were limited to about 50 persons, from the Japanese NIPT working groups, MITI, JIPDEC, and researchers from the United States, France, and Germany. A few other foreign researchers were invited but were unable to attend. In addition, six U.S. Government officials attended as observers, as did one person from the German GMD Liaison Office in Tokyo. The U.S. observers, other than myself, were

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Dr. Robert A. Kamper
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The workshop was organized as follows.

- A half-morning general session (Japanese speakers)
- Two parallel sessions lasting into the night of the first day and half the morning of the second.
 - "Integrated Computing Track"
 - Approach to Integrated Computing session (reports from the three Japanese sub-working groups)
 - Overseas Activities in Integrated Computing session (U.S. & Europe)
 - Informal Discussion on Future Information Technologies (all)
 - Comments on NIPT session (U.S. & Europe)
 - "Optical Computer and Device Track"

- Approach to Optical Computing session (reports from the four Japanese subworking groups)

- Overseas Activities in Optical Computing session (U.S. & Europe)

- Informal Discussion on Future Information Technologies (all)

- Comments on NIPT session (U.S. & Europe)

- A late morning general session titled "Toward International Cooperation," with formal presentations by the Japanese and informal presentations by the U.S., Europe, & GMD.

Shortly after the conference ended, Dr. Kamper sent me a copy of his excellent trip report. Kamper attended the Optical Computing track, while I attended the Integrated Computing track. Because our views on the combined sessions seemed similar, I have decided to merge his report into mine in the following way. In the section on optical computing, all the comments are Kamper's. Comments about integrated computing are mine. Remarks about the combined sessions are a mixture, sometimes quoted, although I take responsibility for the content. For a complete copy of Kamper's report please write to him directly. I also had an opportunity for discussions with the other attendees including Dr. Wong, Dr. Glasser, and Mr. McPhee. Nevertheless, all the comments below are my own and, as usual, do not represent any official policy. If other attendees send summaries to me, I will revise this report to reflect them.

It was the impression of most of the foreign attendees that major aspects of this program are still very vaguely defined. In fact, with the exception of some industrial research projects, the

majority of the factual information that was contributed seemed to be from outside Japan. Partially this was because the researchers came prepared to talk about specific research activities, and the Japanese seemed to be more interested in discussing the general directions of the program. This was reflected in comments as to whether this was a "project," "program," or "initiative." Ignoring the semantics, I have used "program" consistently here without attempting to differentiate it from the other terms.

MITI's description of possible international cooperation was also very vague. The hand-drawn overhead transparency on this was greeted by good-natured howls because of its complexity as well as warm support for the speaker's willingness to present it. The official U.S. response by Dr. Wong was also vague, as there was little to respond to. Nevertheless, several U.S. and European researchers admitted that they were quite interested in accepting money from any source that was handing it out, independent of official government-to-government agreements.

RECOMMENDATIONS

It is not possible yet to know what form this program will take, or even if it will definitely be funded. At the moment it seems a long way from a coordinated project and looks more like a general umbrella under which a large number of research topics will be covered (see Yuba's comments below for a list). The optical computing portion will certainly go forward. The integrated computing portion, where most of the software research is centered, will probably be supported, but I feel that it needs to be more clearly defined first. If the massive parallelism portion results in an effort to design and build a very large system, that activity will attract world class researchers like bears to honey. Aspects of the NIPT program probably overlap significantly with the

U.S. High Performance Computing Initiative.

The preceding program (Fifth Generation Project) did not emphasize international cooperation to the extent that this one appears to do, and so it is very important that all relevant scientific organizations be involved, firstly in the shaping of that cooperation and then in its implementation. The technical aspects of the program also need to be followed and reported outside Japan. Another meeting is to be held 13-14 March 1991 in Tokyo (see page 45). Current plans are for a total attendance of about 400, with 100 from MITI. Talks will be in Japanese and English with simultaneous translation, and it is essential that international organizations participate.

As the program firms up, it would be very healthy to invite several of the key scientists to technical meetings in the United States and elsewhere so they can articulate their ideas personally and discuss them with other (normally skeptical) scientists.

GENERAL SUMMARY

From what I heard in the combined sessions about optical computing, it seemed that this was the better focused of the two tracks. Research has gone from fiber optics to optical interconnections and is now beginning to move to optical computing at the device level. This seemed to me to be entirely related to hardware research. Another colleague who attended this track also mentioned to me that there was almost a complete absence of discussion of software issues there [see D.K. Kahaner and H.J. Caulfield, "Optical computing in Japan," *Scientific Information Bulletin* 16(1), 37-40 (1991)]. However, Kamper felt that this track was not yet focused enough.

The integrated computing track was very poorly focused. It was not clear if any concrete ideas have crystallized yet, particularly in the software area. In

fact, the only software/computer science talk was by Agha (Univ. of Illinois). Oyanagi (Toshiba) did touch on the question of software, but mostly to comment on the difficulties in bridging the hardware/software gap, and his talk focused more directly on technologies for implementation. Opening remarks by Amari (Univ. of Tokyo) discussing the difference between logical and intuitive computing, and the need for new information principles and more basic mathematical theory, did not seem to be followed up by the Japanese in any general way as to how to go about doing this. However, Amari himself has made significant and deep theoretical contributions in neural networks and related learning theory. He was also the organizing chair of this workshop and his ideas are held in very high regard. I was disappointed that he was unable to participate beyond the opening sessions, as his perspective would have been very helpful.

Massive parallelism was mentioned frequently, but I found myself confused by what the speakers actually meant. At first I thought that it referred only to neural computing, especially when terms like "adaptable," "self-organization," "learning," "advanced human interface," and "brain machine" were repeatedly used. Many of the examples, especially those related to optical computing, emphasized neural networks such as for English to Japanese translation and intelligent feature extraction from noisy images. This might perhaps be generalized in some way, such as to genetic computing, which was enthusiastically described by Muehlenbein (GMD, Germany). The Japanese, informally, agreed that genetic algorithms were an important element that was not emphasized strongly enough. Later there were some discussions of dataflow computing by attendees from the Electrotechnical Laboratory (ETL) in Tsukuba, where much of this work has been going on [see D.K. Kahaner, "Electrotechnical Laboratory dataflow project," *Scientific*

Information Bulletin 15(4), 55-60 (1990)]. Eventually I asked specifically if massive parallelism was meant to be more than neural networks, and here the Japanese seemed honestly to be undecided. T. Yuba (ETL), who will play an important role in the management of this program, had a "who knows" expression, and Shimada (ETL), a dataflow researcher, said, "I hope so."

The committee is clearly not interested in the type of massive parallelism that has resulted in the Connection Machine. As far as I could tell, there was no discussion about engineering applications such as those that drive current supercomputing activities. There was no discussion of biological computing, and this was criticized by several attendees. I asked if "soft" computing was related to "fuzzy logic," and after some hesitation one Japanese scientist admitted that he felt the latter was a "quick and dirty" approach and that NIPT was hoping to look at much more fundamental ideas. None of the other Japanese disputed that statement.

Kamper [Univ. of Calif. at San Diego (UCSD)] made the following observations:

Nobody made any commitments and nobody revealed any technical information or even technical opinions that were not already common knowledge. Nishikawa (MITI) stated that the purpose of the meeting was simply to collect ideas as a basis for developing more concrete proposals, and I suppose there was some merit in airing the field of common knowledge, all in one place, with the participants alert to the context. Certainly we all came away with a mutually understood view of the status and prospects of the field. Otherwise there was very little progress to report.

No one person can speak for a democratic nation, so the process of arriving at a consensus must be slow and iterative. It would help to have "straw man" proposals to study ahead of time, so that delegates could go to a meeting knowing in advance what their nations regard as the limits of negotiation. This requires a clear vision of goals of the program, and I sense that we are a long way from that. We need some good, strong ideas supported by arguments that can survive discussion by skeptical people. The origin of the optical computing program at UCSD is a good example to study. Singh Lee's original vision was tempered by the different views of colleagues and funding agencies to become a very productive program. Perhaps we should start with a similar vision for an international program.

At the outset, it was emphasized to the attendees that the talks should be very frank and open; the Japanese had been encouraged beforehand not to wear ties! Nevertheless, many of the public statements were cautious, especially those from Government representatives, both Japanese and U.S. A number of Japanese were clearly uncomfortable speaking to officials who they did not know. This was amplified by the relatively large U.S. official presence, which was definitely a topic of conversation. My own feeling was that the Japanese scientists were very frank and open with me. I believe that they sincerely want Western opinions and hope that the program will have a strong international cooperative component. Of course, the challenge is to arrange that cooperation so that all parties benefit. Perhaps being here more

than a year has helped a little to make communication easier. I have had almost no interaction with MITI or other Japanese Government officials and have no comments about their views.

I would like to suggest that the non-Japanese workshop participants were fortunate to participate in what would normally be considered internal discussions about a program that is still taking shape and were given an opportunity to see aspects of the Japanese decision making process at work. It is difficult to inject a systematic Western view into the Japanese consensus oriented one without both sides being ill at ease. Perhaps a few foreign attendees came expecting a more definitely structured plan. There were a great many "this is my personal opinion" from the Japanese, eventually generating good natured laughter. A Western perspective might be that none of these people can make a commitment for the Government. Perhaps a more generous statement would be that the decision process goes around and around until at last everyone's personal opinion agrees, and then this naturally becomes the official opinion.

On the other hand, a final report is due March 1991, and there does not appear to be much time left to define the program well enough that it can be funded coherently. One of the attendees who often distributes research funds remarked, "I'm glad that I don't have to defend this program." The current phase of the program is viewed as preliminary, ending this month. A feasibility study will begin now and continue through most of 1991. The actual National program, if it is funded, will begin in late 1991. In the United States it is unlikely that a program this vague would be funded without significant changes. The Japanese system may be different; it is almost certain that something will be funded.

COMBINED SESSIONS

Overview of the New Information Processing Initiative

S. Amari (Univ. of Tokyo), who was chairman of this session, opened the meeting with a somewhat abstract overview of the new technologies for information processing. Amari is one of the leading figures in Japanese neural net research, and his papers have international readership. He compared present-day computers and "hard" logic to the human brain and "soft" logic and proposed a 10-year program with flexible targets to develop theories and models, system architecture, and device technology. He emphasized the flexibility of the program's targets. Finally, he remarked that it is just as difficult to cultivate cooperation among institutions in Japan as it is to cultivate international cooperation.

T. Yuba (ETL) gave a summary of the goals that MITI hopes to achieve with the NIPT program. He went on to describe difficulties with conventional information processing, such as

- To represent and process ambiguous or incomplete information
- To describe and solve problems in which a multitude of interrelated information factors are involved
- To adapt or generalize itself to environmental information that is changing dynamically

He also gave some examples of the usage of the term "soft":

Soft Information:

- (1) Ambiguous
- (2) Incomplete
- (3) Multi-modal
- (4) Mutually dependent
- (5) Massive

Soft Control:

- (1) Learning
- (2) Self-organizing
- (3) Optimal
- (4) Adaptive
- (5) Massively parallel

Soft Processing:

- (1) Processing of soft information -- Robust, reliable, high-speed, etc.
- (2) Processing based on soft control -- Learning, self-organizing, optimizing, etc.

Soft Evaluation:

- (1) Evaluation based on soft information -- Robust, reliable, high-speed, etc.
- (2) Evaluation with allowance of uncertainty -- Ambiguous/incomplete criteria, adaptive criteria, etc.

Finally, in the three subdomains of the initiative, theory, technology, and applications, he described the research subjects that the initiative would support:

1. Fundamental Theory -- Theory of soft information processing, which is theoretical foundation for such functions as:
 - Processing of ambiguous/incomplete information
 - Solving of approximately correct problems
 - Integration of massive information
 - Learning and self-organization
2. Fundamental Technology
 - Integrated computing systems with advanced architectures, utilizing

neural computing and optical computing technologies.

- Massively parallel and distributed operating systems and high-level languages.

3. Application Domains

- Recognition via constraint satisfaction and active perception (image/speech processing)
- Problem solving by using soft knowledge and soft inference (expert systems)
- Self-organizing information base and ambiguous query systems (database)
- Open system simulation (simulation)
- Autonomous and cooperative control of multiple robots (robotics)

N. Otsu (ETL) talked about fundamental theory and soft logic. His lecture was essentially a summary of his own research on nonlinear feature extraction in pattern recognition using Bayesian methods to define a best estimate. Many people were puzzled that he chose to present this extremely technical talk at the combined session of the workshop. In the final few minutes Otsu described some impressive applications of his work to an adaptively trainable vision system. Unfortunately, by this time most of the audience had lost the main point. Except for a few in the audience who were well versed in probabilistic logic, not much information was communicated.

T. Kamiya (Univ. of Tokyo) discussed the prospects for optical technology. He started with a brief history of the topic and referred to three reports that summarize the present status: "Optical computing in Japan," edited by S. Ishihara; proceedings of the Kobe meeting, 1990; and the JIPDEC (MITI) Report. Kamper notes that "having read

two of these documents, I can confirm that they cover nearly all of the technical material discussed at this workshop." The Kobe meeting is also discussed in my previously published optical computing article.

Kamiya reviewed the present status of optical devices. Among those devices already demonstrated are: switches with picosecond switching time, optical interconnects for wafer scale integration, an optical system using spatial light modulators (two dimensional) for parallel digital processing, and an optoelectronic neural chip.

For a research strategy, he proposed a focus on optical interconnects and various types of optical computers: dedicated, special-purpose computers; optical digital signal processors; image processors; work stations; intelligent robots; supercomputers and main frames. To myself and many others in the audience, these directions appear perfectly reasonable.

Toward International Cooperation

This session brought in some higher officials from MITI including

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Director
Information, Computer and
Communications Policy Office
Machinery and Information
Industries Bureau
MITI
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Tel: (03) 3501-1511, x3321-5
(03) 3501-2964 (direct)

and

Mr. Taiso Nishikawa
Deputy Director
Industrial Electronics Division
Machinery and Information
Industries Bureau
MITI

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Tel: (03) 3501-1511, x3341-6
(03) 3501-1074 (direct)
(03) 3501-2788 (direct)

Edward Malloy (U.S. Science Counselor, from the Embassy in Tokyo) also attended. An interpreter was present to help avoid misunderstanding, but she was occasionally corrected by bilingual participants. Prepared talks were interspersed with informal discussion, moderated by T. Kamiya (Univ. of Tokyo).

T. Nishikawa (MITI) repeated that this workshop was part of the process to establish a program to follow the Fifth Generation Project when it ends in March 1992. The preliminary study started in 1989 and a final report is due in March 1991, when it will be followed by a feasibility study.

He then carefully defined four distinct types of international cooperation, divided by source(s) of funds, location of research laboratories, and the option of short-term exchange of scientists. All four had the common feature that scientists from both countries participate.

With respect to the NIPT program, he expressed MITI's commitment to international cooperation but stated directly that there is as yet no concrete proposal, and that time and discussion as well as ideas are needed. He then showed a diagram of his personal view of the form the organization of the cooperation should take. It was a very complicated combination of the simpler diagrams he had used to describe his four types. He proposed that a central office should control a pool of funds supplied by Japan, the United States, and Europe. MITI and counterpart Government organizations in the other participating countries should be involved. Laboratories should be located in all participating countries, with exchange of scientists. The central pool should also fund international consortia.

The whole organization should have complete symmetry with respect to national borders. It should operate under the U.S./Japan Agreement on Cooperation in Science and Technology (S&T) and a counterpart EC/Japan agreement. Intellectual property rights should be allocated according to degree of participation and in accordance with the various S&T agreements.

G. Agha (Univ. of Illinois) asked what mechanism will be used by the Japanese Government to choose among the options. Nishikawa replied that a survey team had been sent out before the workshop, but he did not comment on its findings. He stated that the Japanese Government has no intention to press foreign participants to follow concepts it had developed unilaterally. He expects the 1991 feasibility study will be funded in Japan and encourages the United States and EC to organize parallel studies. He declined to suggest the form of these studies but called for a commitment to cooperation.

M.E. Prise (Bell Labs) commented that as an individual he is eager for international cooperation, but as an employee of a U.S. corporation he cannot make any commitments without concrete proposals and the establishment of company and Government policy. Nishikawa replied that he understands the point. He said that the purpose of this workshop is to collect ideas and comments from individual researchers as a basis for further development.

E. Wong (OSTP) presented the U.S. Government view. He explained that the U.S. Government officials at this meeting came as observers, not participants, and were attracted by the prominence of international cooperation on the agenda. He recognized many theoretical advantages of cooperation, such as economy in the use of research and development (R&D) funds that could be used for other means of promoting economic growth in a time

of world-wide capital shortage. But he pointed out that excellence is driven by competition, that Japan has learned better than the United States that cooperation and competition can coexist, and he praised MITI for fostering both successfully. He pointed out that several members of the U.S. delegation represented science and technology agencies that are eager to participate in the early stages of planning, and that in a well designed program individual institutions and national interests are accommodated. Finally, he suggested that this new initiative should be organized under the U.S./Japan S&T Agreement.

G. Agha (Univ. of Illinois) asked what role the Federal Government would have, and pointed out that the United States has a decentralized system in which individual organizations respond mainly to sources of funding, and that he personally was anxious to begin discussions with NIPT staff. Wong recognized our tradition of decentralization and the generally independent nature of scientists. He saw the Government's role as catalyzing and coordinating the effort, with everyone's goodwill. T. Kamiya (Univ. of Tokyo) asked what is the motivation to cooperate. Wong replied that all parties should gain more from a cooperation than they would as individuals. S. Lee (UCSD) remarked that he is attracted to cooperation because he prefers fighting nature to fighting people. He emphasized the need for fairness, considering both past and future investments.

H.W. Muehlenbein (GMD, Germany) presented the European perspective and commented that funding in the EC's ESPRIT program is much larger than NIPT's is likely to be, but that the optical computing component looked about the same. [The major European Community research funding agency is the European Strategic Program for Information Technology (ESPRIT). This has a billion dollar

budget, spent mostly on short-term research in electronic computing. About 5% is spent on optical computing projects. Another, but somewhat less prominent, agency funding optical computer research is the Basic Research in Industrial Technology Agency (BRITE). There is a conference series (ISOC), but the major forum for coordination of research is the series of ESPRIT project meetings.] Muehlenbein remarked that the members of EC are experienced in international cooperation, but it works well for them because ESPRIT has plenty of funds. Without that there would be more conflict than cooperation. He emphasized a point that was taken up by other university researchers, that without the promise of new funds they will not be interested in participation. He advised the governments involved in this initiative to concentrate on that aspect of the organization.

T. Hagemann (GMD, Tokyo) defined the issues as: what to do, what to do with the results (intellectual property rights), and how to do it (organization and funding). The property rights issue should be clarified at the very beginning to avoid headaches later on. He suggested that distributing property rights to the contributing researchers was the best mechanism. Using ESPRIT as a model, he suggested that funds should stay with the contributing organizations rather than being collectively managed or divided up according to the shareholding ratio of the partners. He did not favor the establishment of a central research laboratory, nor the temporary placement of scientists among participating laboratories, but considered that communication and coordination are enough. He believes that consortia should have balanced partners (e.g., company with company, or university with university) and that their funding should also be balanced and come from local sources. He asserted that the most significant effect of ESPRIT

has been to get the European scientists to know one another and to cooperate. Finally, he recommended that Japan approach the EC Commission rather than individual national governments.

W.T. Cathey (Univ. of Colorado) commented that most industrial participation in ESPRIT is on short-term projects only. Industry/university partnerships should not be excluded for long-term work. Also, central management of funds would bring coordination that would not otherwise occur. Hagemann said he was not convinced about the last point. P. Chavel (CNRS, France) agreed with Hagemann, particularly on the virtue of local organization of research with coordination. He felt that funding and participation need be balanced only on average. S. Lee agreed strongly with Muehlenbein's comments about funding. He stated that he is not interested in a zero sum game. Several people in the audience declared that they had been the victims of zero sum games in the past. G. Agha said that university researchers welcome international cooperation, and neither know nor care what attitude the U.S. Government has towards it.

H. Nishimura (MITI) closed the meeting with a few brief remarks and much good humor. He asserted that a mood of trust had been established. (Not everyone would agree. People were very careful about what they said to those they didn't know, and free-form discussion tended to dry up.) He also stated that MITI is drafting a policy to support basic research in Japan.

OPTICAL COMPUTING TRACK

Background

Most people define an optical computing system as one in which some functions are performed by optical devices. These will be accepted to replace the corresponding electronic devices only when they demonstrate a clear

advantage in system performance. It is unlikely that we will see an all-optical computer except perhaps for some very specialized purpose.

The supreme advantage of optics lies in parallel processing. Closely packed and intersecting channels do not crosstalk except at detectors or other nonlinear devices. Interconnection can be made without the energy penalty of mismatched transmission lines, although at present there is another energy penalty from the inefficiency of electrical/optical conversion. One of the goals of optical computer development is therefore a massively parallel digital processor. Another goal derived from this is the exploration of neural networks and "soft" logic. In this respect one of the speakers showed a plot comparing speed and complexity that put the potential performance of an optical computer comfortably ahead of that of the brain of a bee but a long way short of the human brain.

There is research in progress in many parts of the world that has already demonstrated some very respectable devices, such as the self electro-optic effect device (SEED) developed at AT&T Bell Laboratories and an optical neural chip developed at Mitsubishi. Optical interconnects among the chips and boards of an electronic computer are developed almost to the stage of becoming commercial products. Between these and a neural network dreaming away in soft logic lies a very wide field in which to develop new practical systems and devices, and part of this field could be very appropriate for an international collaborative program. The problem is to define which part, and this workshop attempted to do that with very limited success.

Approach to Optical Computing

Planning for the optical computing part of the NIPT initiative has been in the hands of four subworking groups,

who reported their progress in this session.

Y. Ichioka (Osaka Univ.) talked about optical digital computing. The goals are to develop optical parallel computing systems; parallel and distributed optical functional circuits; electronic systems with optical components (e.g., interconnects); parallel inputs and outputs, concurrently addressable; and parallel memory systems. From these he derived a list of the components that are needed: LED and laser diode arrays; functional array devices (e.g., threshold devices); parallel shutter and memory arrays; spatial light modulators; opto-electronic integrated circuits; holographic elements; microlens arrays and high performance lenses; and diffractive optics.

He offered no selection from this list and talked of a 10-year development program leading to an optical mainframe computer.

K. Kyuma (Mitsubishi) talked about optical neural computing. After a discussion of the advantages of neuro-computing and optical implementation thereof, and a summary of the current status of research, he listed the research targets that his working group had identified: neural models for optical implementation, neural models and architectures for direct image processing, modular and expandable models and their optical architectures, and optical architectures for multi-parallel systems. For device development, he emphasized the need for computer-aided design systems specialized for optics.

O. Wada (Fujitsu) talked about optical interconnects. He reviewed the requirements and defined the ranges of computing speed and clock frequency in which optical interconnects will most likely find their place. Then he categorized the various devices that already exist in some form according to function on a three-dimensional plot that was in itself a wonderful example of "soft logic," with axes that change

character from one end to the other, like something out of "Alice through the looking glass." The result was a surprisingly expressive and easy-to-follow global categorization of relationships. He was careful to distinguish the characteristics required for telecommunications from those required for interconnects in computers, and he laid out a logical progression of development that could lead from one to the other. Apart from that, and a comprehensive list of problems that could become research topics, he did not venture a specific course that a formal program should take.

S. Ishihara (ETL) reported the deliberations of the working group on needs for optical computing. He spent a lot of time describing the strategy and mechanics of the committee itself but never came to the point of offering any conclusions. He promised they will be reported in the final report of the working group, due in March 1991. He offered his personal view that it is difficult to get international cooperation on the development of concrete, practical applications. An international program should be on a long-term, fundamental level.

Kamper commented:

It was clear to me from these presentations that none of the four working groups has been able to develop a specific program plan or even to define priorities among the major fields. I doubt if the discussions at this workshop were of much help in this respect. We are a long way from defining a program that could form the basis for negotiations or terms of partnership.

Overseas (Non-Japanese) Activities in Optical Computing

S.H. Lee described the considerations and arguments that were used to plan the rather well coordinated optical

computer program that he directs at UCSD. He presented a clear view of the strengths of optical computing and the components of the supporting technology on which the development effort should be focused. He described a conceptual Programmable Opto-Electronic Multiprocessor (POEM) system that had provided a framework for planning. Lee applied quite general principles to show that an optimized realization of the POEM system would be faster than an electronic system for processing anything larger than a 100x100 array. His group is working systematically to develop all the components needed to realize the concept, including architecture, processors, memory, interconnects, and packaging. His talk was a fine demonstration that it is possible to plan and conduct a systematic program to develop a practical optical computer, even though the job will not be finished for one or two decades and the final form the system will take is unknown as yet.

W.T. Cathey described the program at the Optoelectronic Computing Systems Center, a National Science Foundation (NSF) funded Center of Excellence at the University of Colorado. This appeared to be less highly coordinated than that at UCSD, but it has projects in several areas that will obviously contribute to the development of one or another of the concepts for optical computing that appear promising at present. In fact, proof-of-principle projects are emphasized at the center. One original device he described manipulates a sequence of bits circulating in an optical fiber loop, using an electrically driven crossbar switch. It is capable of time-division multiplexing and generates pretty results.

P. Chavel (CNRS) described research on optical computing in the European Community. He did not cover work in East Europe, which excludes a fair body of Russian work, nor did he include the "Outer Six" countries of the

European Free Trade Agreement (EFTA).

The three major research groups are at Erlangen, Germany; Edinburgh, Scotland; and Paris, France. Some of them have good fabrication facilities, but most focus their attention on device physics and devices that can be made with modest resources. Prof. S.D. Smith, a leading figure in ESPRIT, believes that the highest priority should be given to developing the enabling technologies. Several pretty devices have been invented and demonstrated. These include a nonlinear Fabry-Perot (NLFP) device (Edinburgh) that is optically bistable. This was adapted to GaAs technology in Paris, where extensive work with multiple quantum wells has been reported and an 8x8 electrically addressed spatial light modulator (SLM) using GaAs technology has been demonstrated. There is much work on interconnects both in Paris and in Erlangen and some work on optical analog computing. The overall impression of optical computer research in Europe is of plenty of flourishing, productive device development projects with minimal coordination.

M.E. Prise (AT&T) summarized some highlights of optical computer research at AT&T. After the usual review of the benefits of optical technology in computing, he described some impressive device development. This included extensions of the self electro-optic effect device (SEED) principle (invented at AT&T), especially to arrays of devices, and much work on interconnects, all with characteristic Bell Laboratories quality. Good fabrication facilities can certainly be recognized in the products of a device research program.

Discussion on Future Optical Information Processing

This was planned as a session for spontaneous discussion, following a formal Japanese dinner. It was not very

successful. Several people gave short, unprepared, unfocused talks on what seemed to be a random selection of small topics and general truths. Analog computing and photorefractive devices were discussed, but no conclusion was reached. The audience was very coy about participating in a discussion. Finally the session lapsed into silence. Someone got up with a set of viewgraphs to give a short, prepared description of his own project (a device called VSTEP, similar to SEED), and when he finished the session ended without regret.

Comments on the NIPT Initiative with Regard to Optical Computing

The speakers in this session had been asked in advance to talk and were prepared. Their comments were more in the nature of general advice than critique of the rather formless initiative.

S. Lee shared the experience of planning the optical computing program at UCSD. His view is that an optimum computer would combine electronic and optical functions where each excels, so it is important to look for opportunities to combine technologies. The main focus he chose was on optoelectronic packaging and interconnects, looking towards large arrays with wide bandwidth. As a criterion for comparing technologies he used the operation of an NxN perfect shuffle as a benchmark. He asserted that there is no point in developing a new technology unless it can be predicted to offer at least two orders of magnitude improvement over the technology it is to replace. He said it is necessary to choose among the technical options at an early stage and to have a clear vision of what type of computing one is trying to develop: digital optical computing, neuro (or fuzzy logic) computing, or a database machine. He did not venture to suggest choices for the NIPT initiative.

W.T. Cathey tried a little harder to come to grips with the problem of program definition facing MITI. He pointed to cross fertilization among technologies and to optical communications and display technology as promising contributing fields. He discussed joint research projects and emphasized the importance of answering the basic questions of mutual benefit, complementarity, and funding. He was the first speaker to raise the important topic of funding. As possible topics for collaborations he listed: pattern classification, architecture for optical computing, system specification of devices, impact of massive parallel or very fast interconnects on architecture, and potential neural network applications.

He was also the first speaker to acknowledge that the workshop did not appear to be converging on any definite conclusions. He suggested there should be another meeting with different structure. First, the integrated computing and optical groups should not be separated. Then expert system architects and computer scientists should be brought in to remind the audience what the rival technologies can do, evaluate suggested systems, define needs, and design a suitable architecture. A final report of the meeting should be required before it closes.

In the discussion, a question was raised about whether a university would be capable of mounting a "critical mass" effort. Since both speakers had done just that, the question was not received with much sympathy.

P. Chavel started with S.D. Smith's list of important devices to develop: logic, memory, sources, detectors, spatial light modulators, and micro-optics. He then reminded the audience of a few simple truths: the development of the present day computers cost a lot of money, most of the optical computing devices we have today are many orders of magnitude below the projected performance that makes them attractive,

but a few very specialized systems of very high performance do exist already.

Then he presented a little lecture on general principles, emphasizing the ability of optics to handle many parallel channels in a small volume but discussing the limits set by diffraction and the aberrations of lenses. He suggested that arrays of about a million pixels would be practical and useful for operations such as matrix/vector multiplication, Fourier transformation, and correlation. These are important operations for fixed-shape pattern recognition, symbolic substitution, matched filtering, and "understanding." Apart from these basic principles, he drew no general conclusions.

M.E. Prise started with a careful discussion of the distinction between data links and interconnects. He pointed out that future technology will erase the distinction, but at present it marks the line between commercial products and advanced research. The former are the subjects of competition, the latter is a possible subject of international cooperation. He asserted that there is an organizational problem because people who understand the technical end of the spectrum do not understand the commercial end--not very helpful to the purpose of the workshop.

INTEGRATED COMPUTING TRACK

Approach to Integrated Computing

Planning for the integrated computing part of the NIPT initiative has been in the hands of three subworking groups, who reported their progress in this session.

Theory and New Functions Subworking Group (Kawahara, NTT). The thrust of this presentation was the issue of how to put "intimate" machines into everyday life. That is, what kind of new

functions are necessary for machines to cope with the real world, what kind of theories are necessary to formulate these new functions, and how can they be integrated? Again, the stress was on autonomous systems, heterogeneous information, intuitive information processing, illogical situations, flexible and natural interaction with humans and the environment, etc. Kawahara did not present any new theories but only emphasized that new theories will be needed to deal with information representation, integration, evaluation, learning, and self-organization. He did list several theoretical frameworks in which some of these new theories may arise, including the following:

- Probability -- Pattern recognition, multivariate data analysis, probabilistic inference
- Constraint satisfaction and regularization -- Neural computation, approximation and optimization theory
- Modularization
- Formal treatment of interacting autonomous systems
- Physical and developmental algorithms -- Simulated annealing, genetic algorithms, immune system
- Multiple paradigmatic processing, heuristics

He used visual and auditory processing, as well as robotics examples, to illustrate some of the techniques that are now being used and their difficulties, such as inability to work under noisy conditions, inability to satisfy multiple constraints, fault intolerance, etc. He also described the transformation of ill-posed problems into minimization problems by introducing "subjective" constraints, in much the same

way that regularization adds smoothness constraints. Without going into any detail, he also listed a number of wide ranging applications including

- Music transcription system
- Prosthesis of sensory-motor function
- Autonomous cleaner and maintenance system
- Alert system for social security
- Mesoscopic scale simulator
- Self-organizing database
- Quantum mechanical computer

There was no concrete plan presented, nor specific details, and for me, the speech was far too vague to bite into. I think that most of the other foreign attendees had the same impression and as a result there was almost no discussion. One point I did note, though, was that an important aspect will be research in the area of very advanced human interfaces, including audio, visual, touch, smell, etc.

Neural Systems Subworking Group (Okabe, Univ. of Tokyo). Neural networks (NN) are sufficiently well studied that it is possible to imagine the directions that research might take over the next 10 years, and Okabe articulated several perfectly reasonable ones here. He pointed out that modularization of NN is already taking place, with networks built in serial, in parallel and, to a lesser extent, hierarchically. However, he felt that not nearly enough has been done on recurrent networks with multiple layers, or on learning algorithms for training collections of differently organized NN. Similarly, learning algorithms, primarily with

teacher signals, are common, but self-organizing structures can be much more powerful. He suggested three specific research topics:

- Inclusion of structural development process into conventional algorithms
- Evolutional algorithms such as genetic or chaotic algorithms
- Self-organization of structured neural networks

He also gave one view of the system image of an NN front and back end to a massively parallel processor (MPP), which would be rule based, and focused on symbolic processing. The MPP might be a heterogeneous combination of neural structures, including layered, circuit (randomly interconnected), completely connected, tree, and dynamically connected. The physical organization of such an MPP would be hierarchical, chips 5 cm square (neurons) organized 64 to a board, boards connected via a grid 3x3 at the subsystem level and stacked on planes into a system, and systems connected together somehow. He called this a recursively modular architecture and felt it would be a CMOS MPP supercomputer.

He claimed that a one million neuron system with 2 tera updates (multiplication and addition) per second (2 TCUPS) is definitely within range. For example, Hitachi has already built via wafer scale integration (WSI) a board containing 8 wafers with 100 neurons per wafer. Okabe feels that the technology of a 1,000,000 neuron system can be built using $2E07$ transistors/chip in 1995, with 6-inch wafers and 60 chips per wafer. The neuron circuit would be completely digital, with a learning algorithm using back propagation and fully 8-bit input, output, and weights. (It was pointed out during several sessions that for significant numerical computation, it will be necessary to

have at least 32-bit capability.) This assumes about $1.2E5$ transistors per neuron. A one million neuron system would consist of 1,000 subsystems each composed of 1,000 fully connected neurons. He even showed a slide of this entire one million neuron system on a single board 50 x 70 cm, composed of two rows of 50 WSI cards, each card 20 x 20 cm containing a 6-inch wafer with 10,000 neurons. This part of the program is so much more detailed than the first that it will need no help to get going. Quite the opposite, one gets the impression that it will occur independently of any massive government push.

Massively Parallel Systems Subworking Group (Oyanagi, Toshiba).

This talk was divided into four sub-topics: framework, research themes, software, and hardware. Framework meant robust, reliable, failsafe hardware and adaptable, self-organizing, optimizing, learning software. These are the same words we have heard before, and again at this level no specifics were given. In the context of research themes we do get somewhat more detail. He listed the following:

- Soft Model: Multi-paradigm model integrating object oriented and dataflow models.
- Soft Architecture: Reconfigurable and integrated with a neural network.
- Soft Software: Resource management, load balancing, and a super parallel language are necessary.
- Soft Human Interface: Multi-paradigm interface and interactive environment.
- Devices: Wafer scale integration, optics, high density, cooling
- Processor: High speed, low power consumption

- **Interconnection Network:** High connectivity and reliability (may lead to optical interconnection)
- **Systems:** Maintenance, debugging, integration with neural network

There were no further details given about software except that work needs to be done on parallel languages and that the computational model is probably going to be a combination of object oriented programming and concurrent programming.

Oyanagi felt that by the year 2000 we should expect 20,000,000 transistors on an 8-inch wafer. There would be 1E5 transistors per cell, 200 cells per chip, 30 chips per wafer, 1,000 wafers per stack, and 16 stacks per system. He estimated that four stacks could be built on a 100 x 100 cm board and that a 1E8 cell system would generate about 160 kW; thus heat dissipation would be a significant problem. Nevertheless, he felt that building a BILLION cell system would not be impossible. He then went on to describe a three-dimensional implementation using printed circuits and very large scale integration (VLSI) (not WSI) that is being built by Matsushita:

500K transistors/cell
32 cells/chip
128 chips/board
32 boards/module
8 modules/system

This will give about 1,000,000 cells in one cubic meter. Power dissipation is around 320 kW, cooled by heat pipes. He concluded with a table describing two target systems, one for 1995 and another for 2000:

1995 (silicon)

Design Rule: 0.3-0.5 μm
Integration: WSI or VLSI
Cell: 1E5-1E6

Purpose: testbed & software development
Environment: optical network
2000

Design Rule: 0.13-0.2 μm
Integration: WSI
Cell: 1E6-1E9
Purpose: integrated system
Environment: optical network

Once again, the hardware issues seem very much clearer than the software, and Oyanagi acknowledged this afterwards. Also, there was no suggestion of the software and design issues related to reliability and fault tolerance of such huge systems.

Overseas Activities in Integrated Computing

My description of this session is deliberately brief.

H. Muehlenbein (Parallel Genetic Algorithms)
GMD
Schloss Birlinghoven
D-5205, Sankt Augustin

G. Cottrell (Grounding Meaning in Perception)
Computer Science and Engineering Dept
UCSD

G. Agha (Foundations for Building Massively Parallel Computers)
Computer Science Dept
University of Illinois
Urbana-Champaign

These speakers, like the rest of us, really did not know what integrated computing was and, hence, appropriately spoke about their individual research activities. My own interest was most captured by Muehlenbein, who talked about early random search methods using evolutionary principles in the 1960s.

These were not influential, but new extensions are based on "genetics," that is, the addition of some clever randomness not to the search but to the capabilities of the searchers. This approach appears to be much more powerful and also very suitable for parallelization. Muehlenbein claims that his algorithm beat three other neural network algorithms at large Travelling Salesman Problems and is much faster than any other published algorithm on a benchmark ("beam") Graph Partitioning Problem. He also claims that it is the fastest general purpose unconstrained minimizer. I was not familiar with this, but it certainly caught the attention of the audience. A well written survey of his work, along with a good bibliography, is in his paper "Parallel Genetic Algorithms and Combinatorial Optimization," to be published in the *SLAM Journal of Optimization*. Finally, it is worth noting that research in genetic algorithms is going on in the United States, too. In fact, at the Naval Research Laboratory, John Grefenstette [gref@aic.nrl.navy.mil] has also written a survey paper on a similar topic.

Discussion of Future Information Technologies

While this session was informal in the sense that numerous bottles of beer were available, the discussion consisted of descriptions by Hitachi, Fujitsu, and Toshiba of neural net research projects. Since these were essentially all hardware (although exceptionally interesting), the software people in the audience were hardly in a position to make any serious comments.

Hitachi described a 2.3 GCUPS neuro system built with eight (5-inch) wafers, 144 neurons per wafer (30,000 transistors per neuron), using a 0.8 μm CMOS gate array. The system is 30 x 21 x 23 cm and dissipates about 50 watts. The interesting thing about this system in addition to its speed (about four times faster than previous) is that

the weights and connections are dynamically changeable and that the weight values can be full 16 bits. The speed comes from a clever use of two separate busses, one each in the input and output direction. Learning is implemented via back propagation. Several applications have already been programmed including signature verification and stock prediction. This device was announced formally 3 or 4 days before the workshop.

Fujitsu gave an overview of their own neuro computing research activities. They have built or are working on three different systems including a PC board, but the most interesting is Sandy, a collection of 256 Texas Instrument floating point digital signal processors (DSP) on a ring network. Each DSP is presently functioning as a single neuron, but Fujitsu claims that the software can allow each to be four (or more) neurons. Because of the DSP, honest 32-bit floating point operations are possible. Currently an 8-processor prototype is running. The 256-processor version will be capable of 6 GCUPS for back propagation. Several applications of this were cited, including mobile robot control, stock forecasting, convertible bond rating (this was demonstrated to me during my last visit to the Fujitsu laboratory) and, more practically, a process failure prediction system to be used during steel continuous casting to determine "breakout time," the time at which the cooling process fails. Fujitsu is also experimenting with combining a neural net with a fuzzy reasoning interface.

Toshiba described a 512-processor system organized as an 8x8x8 set of crossbar switches representing the faces of a 3-cube. In other words, any processor can communicate with any other in at most three hops. There were no other details given and the current status of the project was not made clear. It was also mentioned that work is continuing on a Japanese word processor

that uses a neural network to select kanji from input kana.

Comments on Integrated Computing Portion of NIPT

This was the opportunity for the foreign speakers at the integrated computing track to give some opinions about what they had heard. They had been asked to do this in advance. Muehlenbein began by reminding the audience that many of the goals of the Fifth Generation Project are unfulfilled, perhaps because the announced goals were "artificially definite." He felt that many EC projects seemed better thought out, but that to be honest, in 10 years Japanese industry had come much further than European. With respect to the current NIPT proposal, he was happy to see the emphasis on the theory component, which he felt was lacking in the Fifth Generation Project, but also noted that the numerically intensive engineering applications (such as fluid dynamics, etc.) were missing. This was a theme that several of us commented on. He was happy to see a pluralistic, multi-paradigm approach, and was certainly enthusiastic about the possibility of international cooperation. He wondered, though, why Japanese industry was interested, as similar interest is difficult to generate in European industry. (It seems to me that government money is a very good way to generate interest.) He emphasized what we all had been saying, that the software component was almost totally missing and that this was not a project in the usual sense of targets or schedules. Finally, he remarked that hardware speed is not the issue, organization (computational model) and software are more important.

Cottrell listed a number of neural networks that were not discussed, such as multiplicative connections, oscillating networks, and shared weights. (I

had heard some discussion about studying oscillation earlier.) He mentioned the relationship between neural networks and statistics and various other issues such as neuroscience and self-organization. He felt the Human Frontier Science Project was a good model for NIPT and that cooperation should include support for students, postdoctoral candidates, and exchange of researchers. He also mentioned that if the goals of the program were to help all of mankind, why hadn't he heard anything about medicine, environment, or social applications. Personally, I thought that the waters of this workshop were muddy enough with the scientists who participated, and to have included some of these others would have been a disaster.

Agha felt that NIPT should focus on massively parallel processing and work on building basic principles and conceptual development. Shimada (ETL) ventured a comment that he wanted to develop a massively parallel processor, not a neural network. It is not clear how this will evolve.

Bryant (Carnegie Mellon Univ. and Fujitsu) gave a thoughtful description. He felt that the theory portion (computational model and mathematical understanding) was the most difficult to plan, but that substantial progress should be made before any implementation begins. This progress cannot be set by MITI, would take years, and many models would never make it. He felt that programming (languages and compilers) as well as hardware and applications should come after and that perhaps a good view was to develop implementations towards the end of the decade. In other words, if neural network theory began in earnest in 1980, its implementations are only getting serious now. So we might imagine "soft logic" theory developed during NIPT might be more appropriate for implementation during the next 10-year program.

NEW INFORMATION PROCESSING TECHNOLOGIES SYMPOSIUM (SIXTH GENERATION PROJECT)

An International Symposium on New Information Processing Technologies (NIPT), held in Tokyo, Japan, on 13-14 March 1991, is described. NIPT is to be the successor to the Fifth Generation Project.

by David K. Kahaner

INTRODUCTION

On 13-14 March 1991, an open International Symposium on New Information Processing Technologies (NIPT) was held in Tokyo, Japan, attended by almost 400 people, including about 30 from 12 overseas countries. Three months ago, a much smaller workshop was held in Hakone on the same topic; my article on this workshop begins on page 31. Except when required for clarity, I will omit material that duplicates information given in that article. Consequently, the earlier article should be thought of as an important supplement to this one.

WHAT IS NIPT?

There are several parts to NIPT, but the main thread is that some things are easy for humans and difficult (presently) for computers, such as reading and interpreting comics. The reverse is also true: computers seem much better at floating point arithmetic than we are. NIPT seeks to concentrate on those areas where computers are currently weak. These include friendliness, flexibility, processing diverse and parallel information such as speech and image, adaptation, and integration of ambiguous information. Humans can perform

logical symbol manipulation, intuitive thinking based on pattern dynamics, integration of multimodal incomplete information, learning from examples, fault tolerance, self-organization, etc. The Japanese believe that computers should be made more human-like. Until now computer programming has emphasized logical sequential processing, corresponding to activities in the human left brain, but they feel it will be important to build computers that mimic right brain capabilities.

In this article I am deeply grateful to many helpful comments and corrections from Mr. Satoshi Ishihara [Electrotechnical Laboratory (ETL)], Dr. Paul Refenes [Dept of Trade and Industry (DTI) and Univ. College of London (UCL)], Prof. Bruce MacLennan (Univ of Tenn.), and others. In addition, several Japanese participants had an opportunity to review a draft of this article and voiced no specific objections to it.

The most succinct and complete description of NIPT was provided by Professor Takemochi Ishii (University of Tokyo, Department of Mechanical Engineering), who chairs the research committee studying the project. I could not do better than quoting his remarks, which follow. My comments [bracketed] are inserted when appropriate.

Since the 1989 fiscal year, the Research Committee on NIPT has been conducting a 2-year preliminary study for MITI (Ministry of International Trade and Industry) to explore the possibility of a new international R&D (research and development) program to realize advanced information processing technologies that can break through the limitations of conventional computers and must be a basis of the information network society of the 21st century. [A 1-year feasibility study begins now. The program, per se, if approved, will begin in 1992. An official budget has not been announced, but MITI claims this will be around \$30M. There are also likely to be industrial contributions that may be difficult to measure.]

The committee has three subcommittees: Fundamental Theory, Computer Science, and Social Impact, consisting of more than 100 researchers participating from various fields such as neurophysiology, cognitive science, economics, philosophy, as well as computer science and engineering. Here is a perspective of the outcome of the preliminary study as an introduction to the detailed reports by chairs of the subcommittees. [Each of the three subcommittee chairs presented detailed papers at this symposium. The computer science subcommittee was the

largest of these and was broken into two working groups, Integrated Computing and Optical Computer/Devices. These were, in turn, broken into several smaller subworking groups.]

1. Objective: The goals of the NIPT program should be:

- Establish humanized, flexible, advanced information processing technologies that will be the basis of the information network society of the 21st century. [Since the earlier meeting there is now a more definite statement that the focus and goals of the program are diverse, multidirectional, and pluralistic. It was admitted that some research groups will fail, or get lost. I felt that the program has been enunciated much more clearly than previously, although parts are still vague. On the other hand, some Western attendees who were not at the Hakone workshop were confused by its imprecision. One called it "Alice in Wonderland," but I think that progress is definitely being made.]
- Encourage international cooperative researchers to make some contribution to develop fundamental generic technologies in high-tech fields and to construct an international co-prosperous relationship. [The lofty nature of the goals and limited resources available require cooperation and coordination. Overseas participation was welcomed but admittedly difficult to manage. The Fifth Generation Project was thought of as entirely Japanese, whereas NIPT has international cooperation as a major stated goal.]

2. Strategy: These goals will be accomplished through promoting an international cooperative research program to:

- Realize humanized, advanced, flexible computers through integration of logical information processing and intuitive information processing by
- Development of massively parallel and distributed hardware with new device technologies such as optical devices. [At the earlier meeting, it was apparent that building a massively parallel computer was to be a part of this project, but this is the first time I have seen it explicitly stated. In later sessions this was spelled out in more detail but also specifically proposed as something more challenging than that selected by industry, such as a one million processor parallel computer, a fully optical computer, or a neural computer. It was left undecided how a neural computer will be integrated into this program and if the focus will be on a general-purpose computer using a neural engine as one part or on a more specialized neural-optical computer.]
- Controlling the hardware in a flexible and adaptive way based on the theory of flexible information processing. [Later, Amari made clear that bold new theories are needed, and what is envisioned is not an extension of current ideas.]

3. Background and Needs for NIPT

In the 21st century, because of the development of sensor technologies and telecommunication service, the trend for multimedia information processing, popularization of HDTV (high definition TV), and the weight shift from material production to information production, the quantity and variety of information that flows through the society will be expected to increase

explosively. The computational ability of conventional computers seems to be insufficient to process such massive and multimodal information. [It is extremely important to note the role that networking plays in Japan's view of the future. In virtually every plan, application, and product, the existence of high performance networks connecting substantial segments of the society is a given, something to be folded in and used rather than something for which a case needs to be made.]

To cope with the crisis of information explosion in the 21st century, new information processing technologies enabling us to realize revolutionary advanced information processing devices will be needed that have some of the following features:

- Learning and self-organizing ability for software reduction.
- Adaptability for individual users or situations.
- Information integration ability to analyze information, to make synthetic decisions, and to use many kinds of knowledge cooperatively for problem solving.
- Sufficient complexity of systems compared with the complexity of the phenomena that the system treats.
- Affinity for optical communication technologies to enable the integration of communication and information processing.

4. Fundamental Policy: In carrying out this program, the following fundamental policy is important:

- Construction of an international cooperative and co-prosperous relationship in high-tech fields by keeping the door open to foreign companies and universities as well as domestic ones and guaranteeing

impartial distribution of the results. [Several Western governments are already involved in discussions as are a few private companies. Ishii admitted that handling the results was crucial and could eventually become a model for international R&D in generic high-tech fields, and that the Japanese people felt the need to become more global and share world intellectual assets. In particular, he noted that advanced research needed to be used by the developing countries, and that cooperation with their researchers was important. Although several private meetings occurred, there still is no public statement of how cooperation and intellectual property are to be handled. However, at about the time of the symposium, some proposed changes were announced in the way MITI treats patent rights arising out of R&D projects that are funded either by MITI or by NEDO (New Energy and Industrial Technology Development Organization). The proposals have been submitted to the Diet as a revision of the "NEDO Law." The claim is that the measure is intended to promote international research cooperation among the private sectors in order to develop new technology and is a first step toward realizing the government's "technoglobalism" policy. Until now, all patent rights arising from projects funded by MITI have been held by the government. Participating companies have had to pay license fees to use these patent rights. (In the case of projects funded by NEDO, companies can hold up to 50% of the patent rights, but they still have to pay license fees.) Under the proposed new measure, companies can hold up to 50% of patent rights, even if those patent rights arise from government-funded R&D projects.

In addition, companies can use patent rights arising from R&D projects funded by MITI or NEDO free of charge or for a small fee. The law is expected to be passed and go into effect this summer. I assume that the proposed legislation will also apply to research collaborations with universities. Because of MITI's support for Japanese industry, as contrasted to Monbusho (Ministry of Education), which supports Japanese universities, some Western participants were wary about assuring themselves that cooperation will mean that benefits flow in both directions. Perhaps it would make sense to offer up parts of the program directly through Monbusho. I hope as the next study begins we will get even more details of who is going to do what, and with what resources. If this information is open and complete, it will go a long way to alleviate a number of uneasy comments that I heard. See also remarks from P.N. Refenes below.]

- Challenge for creating fundamental and revolutionary generic technologies by encouraging the participation of the universities and national laboratories.
- Shift from R&D for technology itself to R&D for human beings by encouraging the participation of users of the technologies and researchers from related basic research fields such as brain science and cognitive science. [End of Ishii's remarks. Western participants in the symposium who also attended the workshop were impressed with the increased role assigned to biology, a topic whose absence was criticized at the earlier workshop. See also the summary of R. Suzuki's lecture below.]

REMARKS

Both formal and informal discussions suggested that at the moment four major ideas are active. These were also mentioned by S. Amari in his lecture describing the computer science research subcommittee.

- (1) Develop a theory of flexible information processing, parallel and distributed computation, learning and self-organization, neural and optical computation, etc.
- (2) Develop a theory and implement an integrated information processing model of the brain that can be useful for recognition, understanding, and control in a real world of information, such as control by complex speech input.
- (3) Build a (probably) general-purpose, object-oriented, data-driven massively parallel computer system with 10^6 to 10^9 processors, using optical or neural chips.
- (4) Continue research and development on optical computing, including optical interconnects, devices, optical neural computers, and fully optical computers.

With respect to a massively parallel system, Amari described what could be built using technology that would be working within the next 10 years. A 32-bit processing element (PE) would contain 2K words of memory and require 600K transistors. Eight processors would be on one chip, 1K processors would be on a one-board module, and 1000 boards would compose a one million processor module, or system. He emphasized that the NIPT program would only go so far as to develop proof of concept or do the research necessary to overcome bottlenecks. Further work would be left for industry.

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PANEL DISCUSSION

One of the most interesting parts of the symposium was a panel composed of eight well known researchers:

- M.A. Arbib, Univ. of Southern California, U.S.
- R. Eckmiller, Univ. of Dusseldorf, Germany
- A. Hartmann, MCC, U.S.
- B. MacLennan, Univ. of Tenn., U.S.
- P.N. Refenes, Dept of Trade & Industry and Univ. College of London, U.K.
- J. Shimada, ETL, Japan
- K. Toyama, Kyoto Prefecture Univ. of Medicine, Japan
- T. Yuba, ETL, Japan

The topic was "Towards Computing in the 21st Century," and each panelist was given an opportunity to make some formal remarks and then there was to be a dialogue. One or two questions from the floor were allowed to each speaker. Although all of the presentations were exceptionally well thought out and extremely valuable, most of the non-Japanese panelists seemed unable to keep to the schedule and an important opportunity for a real discussion was lost, save for Arbib, who spoke last and was able to make a

few comments about earlier presentations. As readers will discover scanning the summaries below, panelists dealt with very different topics and an interchange among them would have been most useful. My own feeling is that the Japanese should market an overhead projector that displays a large clock on its face showing the time remaining (to be set via remote control by the chair), blinks to alert the speaker when time is almost up, and after an appropriate grace interval turns the projector light off. This would also eliminate the embarrassing need for the secretary to try and catch the speaker's attention with a sign reading "no more time."

Brief summaries of the significant remarks are given below. Eckmiller, Hartmann, Refenes, Shimada, and Toyama submitted papers that are included in the proceedings. Arbib and Yuba gave other lectures that are also in the proceedings, and in those two cases I have used their papers as reference material.

Toyama, a neurobiologist, discussed aspects of cortical machinery that might help in future design of parallel computers. (Another biology paper was presented by Hideo Sakata of Nippon University. I am not qualified to comment on either of these.)

Eckmiller made a very general appeal to use the international cooperation aspect of this project to work on solutions to the Earth's major problems: population, environmental protection, etc. He also pointed out that the European Esprit model was probably not the right one for MITI to follow for cooperation. MITI's Nishikawa responded to a question that as yet there was no contract with any other country, or any real model for how cooperation should be done. On the other hand, I have learned that some negotiations already are underway with Western universities for the exchange of scholars, setting up of research institutes, etc.

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MacLennan commented that the current "hot" computer science areas, artificial intelligence (AI), expert systems, fuzzy logic, etc., cannot cope well with flexibility (too brittle--nice term). He urged the NIPT planners to consider studying how discrete objects come from continuous ones (neural processes and subsymbolic cognition). His paper was not included in the proceedings, but copies can be obtained by contacting the author.

After the meeting, MacLennan forwarded to me some remarks that are quoted below. I believe that they agree with my own observations as well as those of other participants.

One of the most important characteristics of the Japanese initiative, as I understand it, is that it is not a narrowly technological project. First, it is based on a comprehensive vision of "the information network society of the 21st century." This is seen to imply a need for: (1) flexible computing ("intuitive information processing"); (2) adaptive computing; and (3) massively parallel computing, including optical computers. Second, the Japanese are aware that much basic research remains to be done before this vision can be fully realized, and so they are including researchers in "neurophysiology, cognitive science, economics, philosophy as well as computer science and engineering." Furthermore, they apparently realize that the same fundamental understanding of the

cooperative/competitive dynamics of complex systems that informs our understanding of neural networks will also inform our understanding of the multinational projects, societies, and economies that produce them. Thus they are abandoning the top-down, unidirectional organization of the Fifth Generation Project in favor of a bottom-up, pluralistic, cooperative/competitive strategy. All of this shows, I think, a breadth of vision that will carry the Japanese project much further than would the view that the goal is no more than a new computer technology.

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Refenes' presentation was the most focused of the panel presentations in my opinion. He claimed that the NIPT program was ambitious. He pointed out that soft information processing is not yet a theory and, in fact, that there are several competing theories, no accepted model, nor evidence of the emergence of any unifying theory. Developing the technologies necessary is a considerable task requiring large resources and long lead times. Refenes claimed it was unclear if a massively parallel computer should be multiple instruction/multiple data (MIMD), single instruction/single data (SIMD), etc., and that problems of overhead explosion are not solved. He stated that basic system software development is a significant task. He suggests that as much as possible various problems should be treated independently and that objectives should be narrowed. In particular, the architecture should be

decoupled from neurocomputing. Refenes also claimed that high speed was not really necessary for neurocomputing except during training and that neural networks will typically be trained once, off-site, using general-purpose computers. (Arbib disagreed with this; I think I do, too.) Refenes pointed out that there was an important need to provide network development tools and network compilation tools. Finally, he noted that technology transfer was an essential element in international cooperation.

Subsequent to the symposium, Refenes sent me some additional comments specifically related to cooperation. He agrees with most other observers that NIPT is more a Program than a Project, and that a central research facility, such as the Institute for New Generation Computer Technology (ICOT) (Fifth Generation), is inappropriate. He notes:

From the Japanese point of view, there are two main reasons for seeking international collaboration in NIPT: firstly, to establish a strong presence in the world research community and thus "legitimize" their industrial exploitation of world R&D results. The aim is to counteract long standing criticism of the Japanese contribution to global R&D efforts and is in line with the policy of establishing research laboratories in the West (e.g., NEC and Sharp in the U.S.A. and Europe, respectively). Secondly, NIPT requires significant numbers of high caliber researchers which, for many but not all areas of NIPT, are not readily available in Japan.

He also points out that in the past there was not much Western interest in collaboration because it was felt that Western R&D was significantly ahead

of Japan's and that collaboration would have too many one-sided benefits. In many areas, especially those related to device technology, this is no longer true. Collaboration on this current project could provide Western access to Japanese markets (as much by exposure as for any other reason, and also because of the possibility of new markets developing from NIPT technology). This might be particularly true in consumer electronics, as these are likely candidates for intelligence. (I agree emphatically and have repeatedly emphasized the role this part of the industry plays here in Japan.) Finally, Refenes notes that horizontal collaboration, between Japanese companies and Western universities, is likely to happen anyway, especially if NIPT becomes a major funding source. He notes that intellectual property rights is the key to be worked out, that the Eureka model is not a bad one to copy, and that there need not be any central funding source, except to cover pure collaboration costs, allowing participating governments to apply their normal rules.

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Yuba explained that NIPT is thinking about a "super parallel" machine, which he defined as one with more than one million processors. A starting point for this is the ETL EM-4 parallel dataflow machine. He also explained that they have proposed an EM-5, to be built by 1995, with 16K processors, 1.3 T-Ops, 655 GIPS, using an object-oriented model, a universal network,

as well as a robust architecture that uses both hardware and software to adapt to load scheduling.

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Hartmann showed an interesting slide giving the potential payoff of each of three technologies in processing, communication, and storage. (Read this table across.)

| | Proc. | Comm. | Stor. |
|----------------------------|-------|-------|-------|
| Photonics | 3rd | 1st | 2nd |
| Electronics/ Semicond. | 2nd | 3rd | 1st |
| Electronics/ Supercond. | 1st | 2nd | 3rd |

He thought that 21st century computing will be characterized by an additional dimension, processing planar data through volumetric processors. "Dense data planes can be communicated photonically, while a compatible ultrafast, ultradense processing capability could be achieved in superconductor electronics, using a storage hierarchy of semiconductor and photonic storage devices."

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Shimada discussed the pros and cons of optical computers. He gave a clear description of technical problems, but his conclusion that "optical interconnection is strongly advocated as a basis of optical computers" was conservative.

Arbib began by saying he didn't like the term "soft" and suggested the use of "flexible" instead. He felt that the de-emphasis on programming was wrong, and that all computers will need to be programmed. Rather than reducing the need for programmers, we will be making programming easier and also easier to describe more complex issues. Also (similar to Refenes), he suggested that the program set more modest goals, establish benchmarks, and develop specific applications. He felt that 10 years was a very short time and wondered if time lines of 100 or 1000 years would be necessary to computerize "wisdom." His vision of the sixth generation computer is one of "cooperative computation":

The computer will be a problem-solving network rather than a single serial machine. The average user will use an expert system to configure a network of standard components with established network protocols, whereas the advanced user will "program" new networks for new applications, using environments for distributed programming, including design of new components (silicon compilers' mechatronics) and network protocols. Each sixth generation computer will thus be a network of subsystems, including general-purpose engines and special-purpose machines, some of which (such as the front ends for perceptual processors and devices for matrix manipulation) will be highly parallel machines. Some subsystems will use optical computing; more speculatively, some may employ biomaterials. Another key aspect is the use of learning in artificial neural networks, which can adapt automatically to new tasks in a manner based

on the learning principles of the brain. We will also see devices and computers more tightly integrated so the perceptual robotics will be an integral part of the sixth generation design, with computers including robotic actuators and multimodal intelligent interfaces among their subsystems.

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Subsequently, Arbib read a draft of this article and agreed that it correctly summarized the content and spirit of the meeting.

OPTICAL COMPUTING

Last year I wrote a summary of optical computing activities in Japan [see "Optical Computing in Japan," *Scientific Information Bulletin* 16(1), 37-40 (1991)], but other remarks are also given in the NIPT workshop article cited earlier. An excellent survey of Japanese research in optical computing is given in *Optical Computing in Japan*, S. Ishihara, editor, 1990 (Nova Science Publishers Inc., 283 Commack Road, Suite 300, Commack, NY 11725). For additional information contact the editor

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At this meeting, two lectures were presented on this topic, by

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Okoshi explained that about 35 university professors have just launched a Grant-in-Aid Special Research Project, to end March 1994, titled "Ultra-fast Ultra-Parallel Optoelectronics," and his talk centered on three examples of the work associated with that project. He displayed a figure showing operating time versus operating power on which various devices (silicon transistors, GaAs, Josephson junction, etc.) were plotted, along with boundaries associated with cooling, numbers of photons, and uncertainty, showing what kinds of devices will make sense in different regions. For example, with 1 pW power, the uncertainty limit requires no less than 20 ps operations, whereas with 1 mW this can be reduced to 0.001 ps. However, the photon limit, that is, the point below which not enough photons are being delivered to reliably make decisions about "0" or "1," is much more restrictive, forcing operation times of more than 1 ms with 1 pW of power. Details of this work are cited as T. Kamiya, "private communication," in Okoshi's paper, but it was

(firstly in English) published in the Nova book mentioned above (T. Kamiya, pp 407-417). [Thanks to Mr. Ishihara for pointing this out to me.] Finally, Okoshi concluded that "if an ultrafast optical computer is to be realized in the future, we will be obliged to take advantage of the parallel computation capability of the optical approach, because its advantage cannot be emphasized too much on the power-speed trade-off graph."

Okoshi then went on to describe a parallel logic system OPALS, two-dimensional surface-emitting laser arrays, and an experiment in fabricating both AND and EOR units using a semi-insulating GaAs-wafer-based high-mobility epitaxial GaAs layer as active medium. As these have already been published in English, their descriptions are omitted here.

He ended with the general remark that optical transmission is still ahead of optical computing. With respect to the latter, premature research is still working toward prototypes, and many years will be required with lots of room for new ideas. However, some technology is already practical, such as optical memory (CD-ROM), although opportunities are open for innovation. In the near future, optical interconnections will become more important via fiber optics, free space optics, and wave guides. In the former (optical interconnections), we already (1990) can transmit at 10 Gbits/s. Okoshi also showed a table of the rate of improvement in communication capability, which is summarized below.

| Year | Mbits/s | No. | |
|------|---------|-------------|-----------------|
| | | Phone Lines | No. TV Channels |
| 1981 | 32 | 460 | 1 |
| 1987 | 1,600 | 23,000 | 48 |
| 1990 | 10,000 | 150,000 | 200 |

Finally, he pointed out the improvements in long distance transmission capability in 1990, about 10 km using coaxial cable, vs (experimentally realized) 364 km using optical lines, between repeaters.

My impression of this lecture was that it was very conservative, with a great deal of hesitancy to commit as to whether optical computing will really work, and if so how long it will take. The tone was entirely different from that of Huang's lecture. Huang gave the last and one of the most up-beat presentations of the work that his group is engaged in. He began his lecture by noting that today's supercomputer has a clock in the range of a few nanoseconds, while the transistor runs at a few picoseconds, a factor of one thousand difference, which he feels can be made up by use of optical connections. Again, much of this has been published, so I only summarize his conclusions, i.e., he expects that using optical output pads and various architecture modifications will allow 100 Gbit/s output. Using more speculative weak nonlinear optical materials, he also believes that femtosecond reaction times might be achievable. He also stated that "optics can easily achieve over 50 times more connectivity" (parallelism).

SPECIAL LECTURE

A dazzlingly elegant lecture on symmetry was presented by Professor T.D. Lee, Columbia University Physics Department, and winner of the 1957 Nobel Prize in Physics. Nevertheless, as far as I could tell, the only connection with this symposium was his remarks about quantum chromodynamics (QCD) calculations requiring very fast parallel computers. He showed a graph on which speeds of various special-purpose QCD computers were plotted against time. Early machines (mid-1980s) were capable of about

100 MFLOPS; current machines are in the range of 10 GFLOPS, including one (GF11) at the speaker's institution (Columbia) and another (QCDPAX) at Tsukuba University. These are still orders of magnitude below the performance that is required. At exactly the same time as this meeting, a number of high energy physicists were also conferring at Tsukuba to discuss the same problem of computing in high energy physics, and one of the speakers there showed essentially the identical slide as Lee did.

OTHER LECTURES

A few other lectures are worth noting briefly.

H. Tanaka (Univ. of Tokyo) described the "Expectations and Problems in the World of New Info Processing" in a blitz talk loaded with facts and figures, going far too fast for me to take in or get much out of. Here are a few details. He pointed out that ICOT's PIM/P machine will be generating 8 GIPS next year. He also mentioned development of Micro 2000, using $0.1\mu\text{m}$ CMOS, 25- by 25-mm chips with FPU, 64-bit words, 4 PE per chip, capable of 2000 MIPS. Hitachi and Mitsubishi are developing 125x125 connections or more neural chips.

W. Giloi (GMD-Berlin) discussed two research topics that his group has been working on related to methods of programming massively parallel systems. These are virtual shared memory, in which a distributed memory machine can be programmed as if it had shared memory, and virtual processor model, in which the user can pretend that there are as many synchronized processors as are appropriate for the application. He claimed that such ideas are very well suited for real applications such as lattice gauge (QCD) and finite difference computations. As Giloi publishes in English, it is not necessary to detail this further, except to say that he made a very persuasive case (to me) about his activities and seemed deeply involved in system building and testing of these ideas.

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Ryoji Suzuki (Univ. of Tokyo) discussed general principles that biology can teach us about computing. Suzuki is the chair of the fundamental theory subcommittee. These principles are:

- (1) Highly parallel distributed processing, including the architecture of the brain, the role of efferent signals, how information is represented in the brain (including the possibility that chaotic behavior of a network could be a candidate for information coding), and understanding the neuron as a processing unit.
- (2) Learning and self-organization, including the multilevel organization of the brain (molecular, network, behavioral).
- (3) Integrated processing of patterned and symbolic information (this includes unconscious parallel processing and later conscious serial processing in the recognition system, integrated processing in the motor control system, and mutual interaction between these).

THE FIRST JAPANESE KNOWLEDGE ACQUISITION FOR KNOWLEDGE-BASED SYSTEMS WORKSHOP

The first Japanese Knowledge Acquisition for Knowledge-Based Systems Workshop (JKAW-90) was held 25-31 October 1990, one (open) part in Kyoto and an invited (closed) part at Hitachi's Advanced Research Laboratory (HARL). Professor B. Chandrasekaran summarizes the open workshop and Dr. Hiroshi Motoda describes the closed session at HARL.

by David K. Kahaner, B. Chandrasekaran, and Hiroshi Motoda

INTRODUCTION

The first Japanese Knowledge Acquisition Workshop was held as a two-part workshop, an "open" session in Kyoto where more than 300 attendees gathered to listen to mostly invited talks on knowledge acquisition and a "closed" session held at the Hitachi Advanced Research Laboratory (HARL) in Saitama where one invited talk, a panel, and a number of submitted papers were presented.

OVERVIEW

As one might expect, a subject such as knowledge acquisition (KA) can cover a broad territory, and the talks reflected this breadth of the subject matter. Nevertheless, a few categories could be identified. Talks by Clancey, Chandrasekaran, Gruber, and McDermott in the open session and numerous talks in the closed session focused on the relationship between knowledge, tasks, and the domains. Knowledge acquisition as modeling the domain for tasks of different types was a theme that was made explicitly by Clancey and implicitly by others in this group. The talk by Quinlan in the open session and several talks in the closed

session dealt with the problem of learning classification rules from examples. Using explanation-based learning for acquiring knowledge was also discussed. A number of talks discussed what one might call KA support structures, such as hypertext and natural language text processing, to produce intermediate structures that could then be accessed by the knowledge engineer for further formalization. Interview techniques, and computer support for interviewing, also attracted attention. In what follows, Chandrasekaran provides a summary of the proceedings of the open part of the workshop. Following that is a short summary of the closed workshop from H. Motoda.

OPEN SESSION

Detailed Summary

The Kyoto part of the workshop started with a couple of tutorials by Brian Gaines of the University of Calgary and John Boose of Boeing AI Center, both of whom have been very active in putting together a series of international knowledge acquisition workshops. Gaines has developed a comprehensive model of the social and organizational aspects of knowledge acquisition. He

used this framework to motivate the issues, as he saw them, in knowledge acquisition. In his view, the knowledge acquisition bottleneck is still very much with us: we still lack the variety of tools needed to help knowledge engineers transfer knowledge to shells; shells are still quite limited in the kinds of tasks they can help us with; and we still have a variety of problems in validating, maintaining, and upgrading knowledge bases. Nevertheless, there has been considerable progress as well. The first generation of KA tools was based on human interviewing. The second generation saw the emergence of a number of computer-based tools that helped in the acquisition process. In Gaines' view, the so-called third generation tools will provide KA environments supporting a wide range of complementary tools and techniques.

John Boose's tutorial surveyed the development of KA technology by using the concept of mediating representations. By mediating representations he means problem modeling languages that help bridge the gap between experts and computer implementations. In a sense, most of the research in expert systems and KA in the last decade can be said to be in this area. He surveyed manual and computer-based methods

and tools. In the manual category is a variety of ideas such as brainstorming, interviewing, and protocol analysis techniques. Semi-automated methods include shells or KA interfaces that use the structure of the generic problem (e.g., Heracles for heuristic classification, CSRL for hierarchical classification, Aquinas for general analysis problems, and so on) to help structure and represent knowledge. In addition to the tools that support KA for various types of problems are various semi-automated tools that support knowledge acquisition more generically: tools to support interviewing, textual representation (e.g., hypercards), modeling tools, tools to support acquisition of knowledge from multiple experts, and so on. Finally there is the body of research and tools that help in fully automated KA: tools based on machine induction for concept learning (important for classification problems).

The invited talks started with B. Chandrasekaran's presentation on knowledge acquisition for real-time (RT) problems. His work has focused on the close relation between the structure of the task and the knowledge needed for it. He has been part of the movement in knowledge-based systems that has emphasized the task-structure as the mediating agency in knowledge acquisition and knowledge representation. He applied that point of view to the design of knowledge systems for RT problems. He started by noting that all problem solving works by using models of the world, and to the extent that these models cannot be guaranteed complete or correct, no problem solving process can guarantee that solutions generated by it will be correct. In RT problems, the goal of problem solving is to generate action sequences that will keep the environment in desired states in the face of changes and disturbances. Chandrasekaran noted that since success in this enterprise cannot be guaranteed, the best that can be done is to know how to abandon goals that are

not being achieved and replace them with goals that are more likely to be achieved. Thus all realistic RT problems have a built-in goal structure that helps in making goal abandonment and substitution decisions rapidly. Chandrasekaran also noted that power in successful RT problem solving in humans comes about not from complex reasoning at run-time about resources or by various forms of "meta-reasoning" but by avoiding complex run-time reasoning altogether. Instead, power arises from four specific sources: (1) good design of sensor and action systems so that direct mappings from observations to internal states of importance, and from internal states to needed actions, can be made as directly as possible; (2) a precompiled body of knowledge that helps to order goals in terms of priorities and preferences, so that goals can be abandoned and modified as needed; and (3) another body of knowledge that helps to synthesize action sequences, i.e., plans. Chandrasekaran proposed that this form of task analysis is very useful for knowledge acquisition since it identifies what types of knowledge to seek in the domain.

William Clancey proposed a very general framework for qualitative modeling of domains and tasks. Expert systems can be viewed as programs that use and construct models of some system in the world so that it can be assembled, repaired, controlled, etc. In his view, the major difference between conventional computer programs and expert systems is that the models in the latter systems represent processes and structures by relational networks. Control knowledge for constructing such a model can be described as operators that construct a graph linking processes and structures causally, temporally, spatially, by subtype, etc. Clancey did not think that expert systems are models of intelligence as much as they provide a new and powerful way to model systems and processes. He also proposed that "recurrent macrostructures" in

such models--both of objects and processes--can be shared. He related a wide body of work--Heracles-DX, Blackboard-ACCORD, generic tasks, and role-limiting methods in a unified framework.

Hiroshi Motoda presented a joint research program whose aim is to build interviewing systems for KA. Their system supports KA in the domain of logical design of databases. The task description is used by the authors to give the interview system substantial capabilities for knowledge analysis. In particular, they can identify which knowledge is lacking or erroneous by actually solving a problem and refine the knowledge base as it goes through a problem solving process. It helps in making ambiguous knowledge explicit by forcing the user to think about the way a problem is being solved and is able to handle requirements that were not thought of in the beginning. The authors then proposed a general architecture for KA based on their experience with the above KA system. The proposed architecture is intended to incorporate machine learning techniques, especially by failure analysis.

Quinlan is known as the originator of ID3, a very successful inductive learning system for learning classification rules from examples. In his talk he reviewed the progress of such approaches and the wide range of applications in which they have been used. One of the deficiencies of ID3 and related algorithms is that they are not applicable for structured data, i.e., data with complex relationship to other data. Instead of a data set where each object has a fixed number of attributes, in the more complex example, each object may have an open-ended number of attributes and also may be related to other objects by means of an open-ended number of relations. He proposed the use of first-order logic to describe the relations. He described some experiments on learning such relations.

Shigenobu Kobayashi presented a jointly developed survey of the work on KA in Japan. Not surprisingly, Japanese research in this area covered a wide territory. It was clear to me that knowledge systems are a major focus of research in Japan. They reported on a recent study by the Japanese Information Processing Center of a number of expert system projects in Japan and the lessons for KA that resulted from this study. Task analysis and identification of the problem solving functions involved in the task are a hard first step. Domain models can be acquired in the form of generic prototypical libraries without waiting for the system development stage. No uniform formal methods emerged as the most appropriate. This report proposed a general architecture for KA with components to support different requirements of the different stages in the life cycle.

It appears that a number of systems are being developed to support the interview process. Quite a bit of interest seems to exist in guiding knowledge acquisition by task-oriented methods, i.e., by methods that take advantage of the relation between knowledge and the structure of the task. Examples of these methods are the generic task methods of this author and the heuristic classification work of Clancey.

Another idea that has been discussed in the United States for a decade or more is knowledge compilation. (My work with Sanjay Mittal was one of the earliest in this area, which I followed up with work on compiling diagnostic knowledge from deep models. The DART project of Genesereth is another forerunner.) It appears that in Japan quite a few projects are investigating this approach to KA. Qualitative simulation and explanation-based learning are being investigated for compiling high-level rules from structural models of devices.

They reported on a substantial body of research on KA from text. A system called hmU performs automatic model

construction from hardware manuals for computer-aided design (CAD) systems. Research on acquiring concepts from natural language texts was also reported.

There is extensive research on machine learning techniques. Inductive and similarity learning techniques were reported. A variety of research on explanation-based learning was discussed. A new technique called frustration-based learning (FBL) by Motoda was discussed. FBL uses frustrated states during problem solving processes as motive forces for learning. It associates a frustration element with information relevant to it. Case-based reasoning as a way of acquiring knowledge also seems to be an active area of research.

A major initiative is worth mentioning. Advanced Software Technology and Mechatronics Research Institute of Kyoto is setting up a project on a large-scale engineering knowledge base under collaboration with academic and industrial research organizations.

John McDermott reported on the research by his colleagues and him at DEC on making applications programming easier. They are building three tools: Spark, Burn, and Firefighter. To quote from McDermott:

Spark interviews a developer and on the basis of what the developer says about the information available for and the results desired from a task, Spark will select, from a library of predefined computational mechanisms, one or more mechanisms that can collectively produce the results desired on the basis of the information available. Spark will then configure those mechanisms into a problem solving method. Burn will retrieve, from a library of KA tools, the tool associated with each of the mechanisms selected by Spark. It will use those tools

to elicit expertise from the developers and produce an application program by encoding that expertise in a way that will allow it to be used by the problem solving method previously configured by Spark. Whenever the application program is used by one of the developers, Firefighter will ask whether the program has performed correctly and if it has not, will invoke either Burn or Spark to add knowledge to the program or modify the problem solving method ...

According to McDermott, Spark takes its inspiration from the generic task work of Chandrasekaran and from Benett's Roget program. He expects that the insights that will emerge from Spark are as follows. Based on the characteristics of a task (at the nonprogrammer level), appropriate predefined computational mechanisms can be identified and configured to perform the task, and the number of such mechanisms need not be large to cover a large number of interesting applications. Burn is based on the idea that KA can be guided by the problem solving methods and mechanisms. Firefighter is a relatively simple "diagnostician" of the problem solving method or knowledge and uses a variety of techniques to "fix" the knowledge or the method.

Tom Gruber described two knowledge acquisition problems that require the domain expert to formalize and operationalize knowledge that is currently expressed only informally. One is the problem of acquiring strategy: how to elicit strategic knowledge from experts without requiring them to design procedures. The other is the problem of device teleology: how to elicit explanations of the "purpose" of a device (i.e., what functions are served by aspects of its design). A technique called justification-based knowledge acquisition, developed for the first problem,

was used by the knowledge acquisition tool ASK. Gruber discussed how ASK acquired strategies for diagnostic test selection in a medical domain by asking experts to justify specific choices in a diagnostic context. The justification language is a user-extensible set of features that abstract states of the diagnosis in a running knowledge system. Then he described a generalization of the technique that could be used to elicit design rationale for electromechanical devices. In the proposed system, the user justifies a design decision by demonstrating the behaviors enabled or prevented by the designed structure using a qualitative simulation, comparing alternative designs in the same simulation context. Again, features that justify one design decision over another are states of a running computer model of the process--in this case, a simulation instead of a diagnosis.

The human uses his access to the external world and his richer knowledge base by selecting what is relevant among the possibilities afforded by the computational model and providing new vocabulary terms in terms of old terms. Since the knowledge is stated in the language of the machine, and the machine is made to formulate it in the context of its task, the additional knowledge is always operational.

The final talk of the open conference was by Alain Rapaport of Neuron Data, who outlined an architecture that his company is developing to integrate a large number of different types of problem solving and KA modules.

Conclusion

Part of the research in knowledge acquisition closely follows research in the more general issues of knowledge systems. Thus a major part of the material covered in this workshop reflected some of the major advances in knowledge systems research of the last several

years, such as task-specific architectures, classification problem solving in particular, and compilation from deep models. There was also a substantial interest in the knowledge acquisition front-end itself: how to simplify the process of getting the knowledge into the machine. Interviewing, analysis of natural language text, and a variety of learning techniques are the major dimensions of research in this direction. Finally, it is very clear that the Japanese have made a major commitment to knowledge systems. The breadth of applications, the degree of commitment, and the progress reported by Japanese industry, Government, and academia in the knowledge systems area were very impressive to this visitor.

CLOSED SESSION

Approximately 40 people attended the closed meeting. Discussions centered around two main topics: "What is knowledge?" and "knowledge reuse." Many metaphors were used to describe knowledge and knowledge acquisition. All of them generated controversy. Examples of metaphors for knowledge acquisition include "chicken soup," "filtering process," and "bottleneck." A comment was that it might be better to avoid distracting metaphor discussions and concentrate on interesting work. The theme of knowledge reuse raised during the open meeting dominated many of the presentations and discussion. Many systems are attempting to reuse knowledge at different levels to gain leverage during knowledge acquisition (task knowledge, problem solving knowledge, task ontologies). A comment was that it might not be realistic to expect the work to get very far very quickly, since most success in knowledge-based systems seems to come from domain-specific knowledge, not from high-level reusable domain templates or procedures.

B. Chandrasekaran received a B.S. in engineering in 1963 from Madras University in India and a Ph.D. from the University of Pennsylvania in 1967. From 1967 to 1969 he was a research scientist with the Philco-Ford Corp. in Blue Bell, PA, working on speech and character recognition machines. He has been at Ohio State University, Columbus, OH, since 1969. Dr. Chandrasekaran is currently a professor of computer and information science and directs the Laboratory for AI Research. His major research activities are in knowledge-based reasoning, architecture of the mind, and cognitive science. He is editor-in-chief of *IEEE Expert* and serves on the editorial boards of numerous international journals. Dr. Chandrasekaran was an invited speaker at the 1987 International Joint Conference on AI, held in Milan, and has been awarded the University Distinguished Scholar Award by Ohio State University. He is a Fellow of IEEE.

Hiroshi Motoda has been with Hitachi since 1967 and is currently a chief research scientist at the Advanced Research Laboratory, Saitama, Japan. He heads the AI group. His current research includes machine learning, knowledge acquisition, knowledge compilation, and qualitative reasoning. Dr. Motoda received his B.S., M.S., and Ph.D. degrees in nuclear engineering from the University of Tokyo. He is now on the board of trustees of the Japanese Society for Artificial Intelligence and on the editorial boards of the *Journal of Knowledge Acquisition*, the *Journal of the Japanese Society for Artificial Intelligence*, and the *IEEE Expert*.

SX-3 BENCHMARKS FROM SWISS TEAM TESTS

This article presents the benchmarks from Swiss team tests on the NEC SX-3/12 and SX-3/14 supercomputers made August and December 1990.

by David K. Kahaner

Several times over the past year,

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has been in Japan as the leader of a team to evaluate supercomputers for possible use in Switzerland as a national supercomputer. (I've known Dr. Friedli for many years since I spent a sabbatical at ETH.) Now a decision has been made to acquire an SX-3 to address supercomputing needs in Swiss research universities and institutes. A two-processor SX-3/22 is to be running by October 1991, with plans to upgrade this to a four-processor model afterwards. The SX-3 that is being installed will have 1 GB of main memory, 4 GB of extended memory, and 70 GB of disk storage, including 20 GB of high speed disks. A 1-TB cartridge system and tapes will be available for archiving. The computer center will be located in the small city of Manno, near Lugano, but operated by ETH Zurich. Access will be provided by the Swiss national university research network, SWITCH.

As part of the decision-making process, a number of real application programs were collected among the supercomputer users at Swiss universities in early 1990. They were to serve as a basis for extended tests to measure single program and throughput performance. Friedli has provided me with summaries of their benchmark tests, which are further summarized below. (A more complete description will appear in *IPS Windows*, No. 2, 1991, which can be obtained by contacting Friedli.) The tests were based on unaltered versions of the programs. No changes were permitted except those necessary to run the program on one processor; compiler options were permitted, but compiler directives were not permitted except to replace those directives already contained in the program. Similarly, program library routines were not permitted except to replace those already contained in the program. (Some of the programs had been running on Cray computers and hence had some directives included or had been optimized in a greater or lesser way.)

In the table below, the NECSX-3 is compared with a Cray Y-MP/8128, with eight processors, 128 MW (megawords) of main memory, and a clock time of 6.0 ns. UNICOS(5.1) and CFT77(4.0)

were used. The Cray tests took place at Cray Research in August 1990. The SX-3 tests took place in December 1990, on an SX-3/22, with two processors and two pipe sets each, 1 GB main memory, 4 GB extended memory, and a clock time of 2.9 ns. A model /24 was also tested. In both cases only one processor was used. A prerelease version of SUPER-UX(R1.1) and a prerelease version of FORTRAN77/SX(R1.1) were used.

The results below were measured on a single processor. The performance ratios given in the table were obtained by computing the ratio of CPU-times measured on the two systems. Friedli noted that the SX-3 is at the beginning of its life cycle and that further improvements can be expected, and that hand tuning of these programs may significantly improve performance. A brief description of the programs follows the table.

For reference, several Linpack results are also given; 100S refers to 100 equations scalar mode, 100V refers to 100 equations vector mode, 1000 refers to 1000 thousand equations, best effort test. The same program may appear several times, such as FANTOM-1, FANTOM-2, referring to different cases, i.e., different input data.

| <u>Program Name</u> | <u>SX-3/12</u> <u>Speedup</u> <u>vs YMP/1</u> | <u>SX-3/14</u> <u>Speedup</u> <u>vs YMP/1</u> | | |
|--|---|---|---|---|
| CHEASE-3 | 1.3 | 1.3 | CHEASE: Plasma Physics. Cubic Hermite Element Axisymmetric Static Equilibrium. Grad-Shafranov equation in axisymmetric geometry, produces a mapping for stability code ERATO. | GLOBE: Meteorology. Numerical model for the simulation of an incompressible fluid on a rotating sphere. |
| FANTOM-2 | 1.5 | 1.5 | | |
| BBINTER-1 | 2.0 | 2.0 | CIRC: Computational Fluid Dynamics. Computational Investigation on Rotational Couette flow. Unsteady turbulent flow through plane or curved channels. | MCRG32: Elementary Particle Physics. Monte Carlo Renormalization Group calculation for four-dimensional (4D) SU(2) lattice gauge theory on 32^4 lattices. |
| LINPACK100-S | 2.1 | 2.1 | | |
| SECOND/S-4 | 1.8 | 2.1 | | |
| PWSCF-1 | 2.0 | 2.2 | | PWSCF: Solid State Physics. Plane waves pseudopotential local density self-consistent calculation of the band structure and total energy for a solid. |
| ZETA-1 | 2.3 | 2.3 | | |
| CYL3D-2 | 2.3 | 2.3 | | |
| CHEASE-2 | 2.3 | 2.5 | CONV3D: Image Analysis (CT and MR). Three-dimensional (3D) convolution using a separable symmetric kernel for medical data. Image enhancement, smoothing, edge detection. | SECOND: Integrated Device Simulation. 3D semiconductor device simulation by the finite element method. |
| LINPACK100-V | 2.5 | 2.5 | | |
| FANTOM-1 | 2.6 | 2.6 | | |
| MCRG16-1 | 2.3 | 3.3 | CORES: Elementary Particle Physics (Hadrons). Inversion of Fermion matrices in lattice gauge theory by the conjugate residual method. | TERPSICHORE: Plasma Physics. 3D ideal magnetohydrodynamics stability program. |
| CYL3D-3 | 3.3 | 3.4 | | |
| T1XY-1 | 2.6 | - | | |
| GLOBE-1 | 3.5 | 4.3 | | |
| MCRG32-2 | 3.0 | 4.6 | | |
| CORES-1 | 3.8 | 5.5 | | |
| CONV3D/C-4 | 3.7 | 5.6 | | |
| CONV3D/R-4 | 2.6 | 5.6 | | |
| CONV3D/C-3 | 4.3 | 7.1 | CYL3D: Computational Fluid Dynamics. Finite volume solution of unsteady incompressible Navier-Stokes equations. | T1XY: Molecular Spectroscopy. Flexible models for intramolecular motion, a versatile treatment and its applications to Glyoxal. |
| TERPSICHORE-1 | 5.3 | 8.5 | | |
| LINPACK100 | 6.7 | >10.0 | FANTOM: Molecular Biology. Energy refinement of polypeptides and proteins. | ZETA: Integer arithmetic. Computing with arbitrary precision. |
| BBINTER: High Energy Physics. Particle tracking of particles in a high energy colliding beam storage ring. | | | | |

A REVIEW OF JAPAN AND JAPANESE HIGH-END COMPUTERS

This article describes the latest supercomputer systems offered by Nippon Electric Company (NEC), Fujitsu, and Hitachi and gives an overview of their operating systems and current installed base, with a comparison to the European supercomputer installed base. A reference is made to the systems installed by IBM and Cray in Japan. The fact that supercomputers were chosen is merely tactical, but these systems do convey very clearly the technological strength of a manufacturer since supercomputers are always built with state-of-the-art technology. The first two sections provide background material for understanding Japan as a nation. The conclusion tries to predict what will happen in Europe in the large-scale computing area over the next few years and offers the author's opinions on how best to profit from the situation.

by Sverre Jarp*

INTRODUCTION

Japan with only 123 million people, half of the population and 1/25th the geographical size of the United States, has now risen to become an economic giant. Although the U.S. gross national product (GNP) is still almost twice as big as that of Japan (\$5 trillion against \$2.7 trillion in 1989), the growth of Japan's GNP is higher and the GNP per capita overtook that in America a few years ago. Additionally, the Japanese economy is extremely solid, with a trade surplus of \$65 billion annually, whereas the United States has a deficit of a similar size (\$50 billion in 1989). Japan has, therefore, become a country with formidable financial resources to back her broad electronics industry and her other critical industrial sectors.

The future of the vital domain of computer technology is certainly going to be decided between the triangle formed by the United States (or the North American continent), the European countries, and the Pacific Rim (mainly Japan, but also Korea to some extent) over the next few decades. The reason for including Europe is the fact that after 1992 Europe will be the biggest single market in the world; this will not only stimulate Japan and the United States but also the (embryonic) European computer industry itself. It is hoped that this article will help people in Europe understand Japan's success in building up a computer industry that is today both broad and strong.

About 30 years ago, Japan was entirely dependent on American computing equipment (mainly made by

IBM). To reduce its dependency on foreign systems, Japan employed a scheme of strong governmental support for reproducing other companies' computer designs and began to build up its own computer industry. For about two decades Japan was largely content to produce mainframes that imitated the IBM/370 systems, selling them in the local market with a Japanese MVS (multiple virtual systems) look-alike operating system, or as plug-compatible machines abroad. The Japanese manufacturers would typically wait for IBM to make a new announcement and then announce "compatible" systems within a given time delay.

In recent years we have seen several changes in this scenario:

* Mr. Jarp spent the summer of 1990 in Japan to study the relevance of Japanese computers to the European community and to his laboratory (CERN). Thus this article is written from a European point of view with a European readership in mind.

- First of all, Japanese companies now dominate the domestic market by providing an impressive 80% of all computer equipment. Japanese technology is now state of the art, and this has led to a self-assurance among the Japanese where they no longer wait for American vendors to announce new products before they come out with similar products.
- The large Japanese manufacturers have expanded beyond mainframes into supercomputers and are today claiming to have the fastest supercomputers on the market.
- UNIX is about to remove the burden of having to stay compatible with IBM's proprietary operating system and should give the Japanese a greatly improved marketing platform for selling their systems in Europe and in the United States.

The best demonstration of the vigor of the computer manufacturers is the list of events that occurred at around the same time as the author's visit to Japan (July-August 1990):

- | | |
|----------|--|
| May: | Fujitsu's new supercomputers start shipping (VP-2000 series) |
| Jun 12: | Hitachi announces new mainframe series (4-way M-880) |
| Jul 4: | NEC announces new mainframe series (6-way ACOS-3800) |
| Jul/Aug: | Fujitsu announces ICL purchase |
| Aug: | NEC SX-3 available for benchmarking |
| Aug 30: | Fujitsu announces new VP models, new version of UNIX |
| Sep 4: | Fujitsu announces new mainframe series (8-way M-1800) |

In particular, the last announcement, which happened "coincidentally" the day before IBM made its biggest announcement in 25 years, can probably be taken as a clear sign from the Japanese that they want to be considered in a position of technological leadership.

In this article, the Japanese producers of large-scale computers (Fujitsu, Hitachi, and NEC), both mainframes and supercomputers, will be analyzed, and their strengths or weaknesses will be indicated. The situation with Cray and IBM in Japan will also be briefly reviewed. It was beyond the scope of this article to cover the other partners in the broad computer (and electronics) industry in Japan as well as new development areas like massively parallel computing.

BACKGROUND

Japan's Demography and Geography

As already mentioned, Japan has 123 million inhabitants living on about 372,000 km². This corresponds to a population density (331 inhabitants/km²) that is one of the highest in the world after Bangladesh, South Korea, and Holland. The geographical size, however, corresponds to that of Finland in Europe or the State of Montana in the United States. (The population in Montana is less than 1 million.) Japan consists of four big islands (Hokkaido, Honshu, Shikoku, and Kyushu) and innumerable smaller ones. The main population lives on Honshu (78%), followed by Kyushu (11%), Hokkaido (5%), and Shikoku (4%). The Japanese islands have always been rather hostile due to climatic and meteorological hardships. For this reason the population inhabits the plains that used to provide (and still provide) the best rice-growing capabilities. A large proportion of the Honshu population is

consequently to be found in the Kanto Plain surrounding Tokyo or the Kansai Plain surrounding Osaka.

Does Japan Inc. Exist?

Many people wonder whether "Japan Inc." exists or not. There seems at least to be a great deal of loyalty to the country. As mentioned earlier, this may be linked to the way the Japanese had to structure their society simply to maximize the probability of survival on some rather inhospitable islands. Today one finds a lot of loyalty inside companies; the companies themselves are often faithfully integrated inside groups (Keiretsu or others). Furthermore, the Government through the Ministry of International Trade and Industry (MITI) is able to establish projects where there is patriotic participation across the industrial sector, allowing for transfer of technology. The net result is a kind of a magnet that has a strong force because its individual domains are aligned.

Some people may find this discussion misplaced, but the author believes that Japanese economical and technological strength must also be viewed against Japanese sociological order and behavior.

Exchange with the Western World

One of the West's big problems vis-a-vis Japan is the fact that so few Westerners go there, either to live or to visit. Whereas in 1988 there were 195,000 Japanese living in North America (including Hawaii) and 80,000 in Europe, there were only 31,000 Americans and less than 10,000 Europeans in Japan. When we consider that the European population is about three times that of Japan, this becomes an underrepresentation of a factor of about 25!

Altogether the Japanese are keeping more than half a million people abroad to make sure Japanese interests are well covered in other countries. Many Europeans also stay abroad, but, as described, they are very unlikely to be found in Japan.

Similar exchange problems can be demonstrated with tourists. Whereas 7 million Japanese went abroad in 1988, only 1 million tourists visited Japan. Looking at the United States, one finds that 2.4 million Japanese visited there but only 200,000 Americans "returned" the visit. Again the ratio is no better for Europe.

It could be argued that the lack of first-hand experience with Japan leads to a clear lack of knowledge about the country in our society. We do not have adequate knowledge about the country, the people, their history, or their ambitions. Clearly both the language and the culture in Japan are reasons for some of the unwillingness on the part of Western people, but it is firmly believed that given the importance of Japan in today's world, the West has no other choice than to keep itself well informed about the Japanese. We need factual and first-hand information about Japan and its people to allow us to judge their strengths as well as their weaknesses.

Finally, the Japanese are in the privileged position that they master English well enough to be able to absorb all written material that is issued in the West. Our problem, however, is the fact that although a large amount of written material is issued in Japan every year, only a very small portion of this material is ever read or translated into English (or other Western languages).

JAPANESE ELECTRONICS COMPANIES

This article does not cover all the Japanese companies in the semiconductor, electronics, or computing fields,

like Sony, Matsushita, Toshiba, or Omron, but it is important to review how broad and strong the Japanese electronics industry really is. To that extent a list of the world's most profitable companies has been included. Although IBM is second in the list (after Nippon Telephone & Telegraph), the top of the list is packed with Japanese banks (Bank of Japan, #3; Sumitomo Bank, #7; Fuji Bank, #8; Mitsui Taiyo Kobe Bank, #10; Dai-Ichi Kangyo Bank, #11; Mitsubishi Bank, #12; Sanwa Bank, #14), followed by an impressive list of the main Japanese electronics companies:

| <u>Company</u> | <u>Rank</u> |
|---------------------|-------------|
| Hitachi | 17 |
| Matsushita Electric | 24 |
| Toshiba | 40 |
| NEC | 50 |
| Sony | 61 |
| Fujitsu | 71 |
| Nintendo | 89 |
| Mitsubishi Electric | 95 |
| Sharp | 105 |
| Sanyo Electric | 106 |

In contrast, Europe's electronics industry can only point to Siemens (46) and BASF (158). Similarly, the United States (apart from IBM) can only point to Hewlett-Packard (HP) (128), DEC (130), and Motorola (138). Clearly the Japanese success in computers is related to the success and the strength of the electronics and semiconductor industries.

Additionally, it seems important that the Japanese Government through MITI has managed to get the large companies to line up behind Government projects like the VLSI project, the 5th generation project (with the 6th coming), the 10 GFLOP supercomputer project, and now the image-processing (Ga-As) project and others. The fact that the resulting implementations of a product can then be fairly similar across the

participating companies does not seem, surprisingly, to be a problem for the participants.

The next sections will review Fujitsu, Hitachi, and NEC. All three companies are very large (in terms of annual sales) and they are all extremely active in the semiconductor field and telecommunications, as well as in the field of general-purpose computers and more recently supercomputers. All three companies enjoy a healthy annual growth, both in terms of revenue and number of employees.

Fujitsu, Ltd.

Founded in 1935, Fujitsu is the "youngest" of the three Japanese computer giants. It specializes in three fields: information processing (IP), which covers computers, peripherals, and others; telecommunications (TC), which covers switching systems and transmission systems; and electronic devices (ED), which covers semiconductors and electronic components.

By comparing computer sales in Japan, one discovers that Fujitsu is the market leader with sales of about ¥1.4 trillion (approximately \$10 billion) in 1989, ahead of IBM with ¥1.19 trillion, NEC with ¥1.17 trillion, and Hitachi with ¥0.92 trillion. Fujitsu also had the highest growth rate with 14.6%. Among its divisions, IP represents 66% of total sales, TC 16%, and EC 14% (with 4% other activities). The Fujitsu Group (including all subsidiaries) had 104,500 employees in FY89 and expanded to 115,000 employees in FY90. Total income amounted to ¥2.35 trillion yen in FY89 and ¥2.55 trillion in FY90.

Hitachi, Ltd.

Started in 1910 as an electrical repair shop for a copper-mining company in Japan, the Hitachi Group is now the 17th largest company in the world with five diversified operating divisions

(Power Systems and Equipment; Consumer Products; Information and Communication Systems and Electronic Devices (ICS/ED); Industrial Machinery and Plants; Wire and Cable, Metals, Chemicals, and Other Products). Total sales in FY89 were ¥6.38 trillion and the total staff was 274,000. In FY90 sales were ¥7.08 trillion and the staff had grown to 290,800.

ICS/ED produces a very broad range of equipment including computers, computer terminals and peripherals, workstations, magnetic disks, Japanese word processors, telephone exchanges, facsimile equipment, broadcasting equipment, integrated circuits, semiconductors, picture tubes, CRT displays, liquid crystal displays, magnetrons, test and measurement equipment, analytical instruments, and medical electronics equipment. ICS/ED represents 33% of the total sales.

Nippon Electric Company (NEC)

Founded in 1899 as an importer and manufacturer of communications equipment such as telephone sets and switching equipment, NEC belongs to the Sumitomo Group (Keiretsu) and used to be called the Sumitomo Electric Company. Today NEC is ranked 39 in the world with five branches to its corporate NEC-tree: Computers and Industrial Electrical Systems (43% of total sales), Communications (26%), Electrical Devices (19%), Home Electronics (7%), and New Opportunities (5%), all of it based on a solid technology foundation.

Total sales in FY89 were ¥3.1 trillion and the total staff was 104,000. In FY90 sales were ¥3.3 trillion and the staff had grown to 115,000. It is the world's leading producer of semiconductors (ahead of Toshiba and Hitachi), one of the largest producers of telecommunications equipment (half the

size of AT&T), and the fourth largest computer manufacturer (behind IBM, DEC, and Fujitsu).

SUPERCOMPUTER EVOLUTION

Less than a decade ago there were no Japanese supercomputers. The first models were announced in 1983. Naturally there had been prototypes earlier (like the Fujitsu F230-75 arithmetic processor unit (APU) produced in two copies in 1978), but Fujitsu's VP-100 and Hitachi's S-810 were the first officially announced versions. NEC announced its SX-1 slightly later.

The last 7 years seem to have been hectic. Two generations of machines have been produced by each manufacturer, and model improvements have also been offered during the life span of these machines. During 7 years about 150 systems have been installed in Japan (with relatively few installations outside the country), and a whole infrastructure of supercomputing has been established. All major universities have supercomputers, most of the large industrial companies and research centers as well, and there are well established supercomputer research institutes and industry observers.

Initial Development of Japanese Supercomputers

Based on their own success with mainframes and the success of the Cray-1 and the CDC Cyber 205, the Japanese decided in the late 1970s to start producing vector-based supercomputers. The first versions were rather primitive, but in a short period of time all three manufacturers have gone from basic implementations to versions that today are considered to be among the best in the world. This is a remarkable achievement and underlines the fact that a company that possesses the

underlying technology can relatively easily progress to the point of mastering logic design and the ensuing implementation complexity.

The Japanese supercomputers were initially oriented towards parallel pipelines featuring multiple floating-point units always governed by one control processor. With the advent of the latest generation of systems from Fujitsu and NEC, these supercomputers have added the dimension of multiprocessing; Hitachi's next system is bound to do the same. The change logically follows from the fact that only computing problems with long vectors and the right mix of floating-point instructions could expect to move towards peak performance in the early versions of these supercomputers. Multiprocessing adds a dimension of versatility to the hardware, but the price to pay is added complexity in the software requiring the basic operating system, the compilers, the libraries, and the applications to be made aware of this architectural feature. In contrast, the design of the Cray X-MP took almost the opposite approach, with multiple CPUs, each featuring only one add and one multiply single-pipeline functional unit. It is expected that in the future all systems must include both multiprocessors as well as multiple pipelined functional units per processor to remain competitive. We should therefore expect the Japanese to increase multiprocessing to 8, 16, or more and Cray and others to offer more pipelining per CPU. According to Cray Research, its next machine, the C-90, will offer 16 CPUs, with two sets of pipelined add and multiply floating-point units per CPU.

All three Japanese manufacturers currently employ the scheme of driving the vector processor at half of the scalar cycle time (by using a minor cycle time and a major cycle time). Cray-2 employed a similar scheme of minor cycles, but

both the Cray X-MP and Y-MP employ full cycles. Whereas this is good for the vector performance, it can lead to an aggravating imbalance in the total system, since the scalar FLOPS are orders of magnitude lower than the vector FLOPS. Such systems can run the risk of being suitable for only a narrow set of applications, demanding general-purpose systems for the applications that do not vectorize well. In other words, they promote the classical front-end back-end combination.

High-End Development Philosophy

Whereas the original supercomputers in Japan were developed from the existing mainframes by adding vector processors, a decade later the Japanese have now moved into a position where they concentrate the development on supercomputers and obtain the mainframe computers as a "by-product" by employing the scalar processor of the supercomputer as the general-purpose processor in the mainframes. Clearly the memory system has to be somewhat redesigned, but the technology remains the same. This philosophy allowed NEC recently to announce the COS/3800 6-way mainframe processor based on the SX-3 and Fujitsu to announce the M-1800 8-way system based on the VP-2000 processor design.

Financially this approach must be very attractive. It allows the research and development (R&D) needed to develop competitive supercomputers to be amortized not just over a few dozen of these but rather over several hundred supercomputers and mainframes combined.

Vis-a-vis other manufacturers, Cray in particular, this seems to be a strong competitive advantage for the Japanese and may provide one explanation of the apparent cost effectiveness of their hardware systems. The philosophy of IBM and DEC of expanding their

mainframes to supercomputers by the addition of a vector facility should offer a similarly attractive cost advantage.

Installed Base History

Several lists exist of supercomputer installations in Japan. This article is based on an updated version of a list circulated by D. Kahaner (Office of Naval Research Asian Office). The Appendix lists detailed installations for each manufacturer. By analyzing the installation dates it can be shown that up until 1983 there were only two supercomputers in Japan (both Cray-1s) (see Table 1). In 1983, as already stated, the first domestic systems were delivered, but until the end of 1985 there were less than 30 systems installed. Between 1986 and 1988, three "golden" years, about 30 supercomputers were installed each year. Although the lists available may be incomplete concerning the last 2 years, there is strong evidence to conclude that the Japanese market has now come to a point where market growth will definitely be lower.

Table 1. Systems Installed by Year in Japan

| Year | No. |
|-------|-----|
| 1980 | 2 |
| 1983 | 3 |
| 1984 | 8 |
| 1985 | 13 |
| 1986 | 33 |
| 1987 | 29 |
| 1988 | 31 |
| 1989 | 16 |
| 1990 | 16 |
| Total | 151 |

Comparison Between Japan and Europe

Although the aim of this article is to review high-end computing in Japan, it may be instructive to compare Europe

and Japan in terms of supercomputer installations. In 1990 the Japanese distribution (both excluding and including vendors' own installations) was thought to be as shown in Table 2.

Table 2. Supercomputer Distribution in Japan

| Manufacturer | Exclusive | Inclusive |
|--------------|-----------|-----------|
| Fujitsu | 63 | 73 |
| Hitachi | 18 | 29 |
| Cray | 26 | 26 |
| NEC | 18 | 21 |
| CDC/ETA | 2 | 2 |
| Total | 127 | 151 |

A certain subset of IBM's 3090 should be added to these numbers. The Department of Defense (DOD) rules for export of supercomputers would suggest the addition of all 3090 systems (model 180 or higher) with at least one vector facility (VF) and all 3090-600S or 600J (VF or not). It is estimated that about 65 such systems exist in Japan, but it was not possible to establish a detailed list of IBM installations for the verification of this number. The number of vector facilities is estimated to be about 110.

In Europe the supercomputer distribution is quite different according to recent estimates (Table 3).

Table 3. Supercomputer Distribution in Europe

| Manufacturer | No. |
|-----------------|-----|
| Cray | 71 |
| Siemens/Fujitsu | 10 |
| Amdahl/Fujitsu | 7 |
| CDC/ETA | 6 |
| NEC | 2 |
| Total | 96 |

The IBM systems (DOD-categorized 3090s) exceed 100. One noticeable difference is the European Academic Supercomputing Initiative (EASI) that promoted 3090-600 systems (with 6 VFs) in several European academic institutes. There are 18 EASI sites: RWTH Aachen (G), CEA Paris (F), CERN Geneva (CH), CINECA Bologna (I), CIRCE Paris (F), CNUSC Montpellier (F), DESY Hamburg (D), ETH Zurich (CH), FCR Barcelona (E), GSI Darmstadt (D), IN2P3 Lyon (F), KFK Karlsruhe (D), KUL Leuven (B), Rome University (I), SARA Amsterdam (NL), Vienna University (A), TU Braunschweig (D), and UMEA Skelleftea (S). Adding RAL (UK), IBM Bergen Scientific Centre (N), and ECSEC in Rome (I), where 3090-600/VF systems also exist, one finds that scientific or university sites alone account for more VFs than Japan has in total. Nevertheless, the total sum of supercomputers, about 200, is the same. This leads to the conclusion that the installed base of supercomputers per capita is at least a factor three better in Japan than in Europe. Given that supercomputers are basically advanced tools for industry, research, and education, this imbalance represents a real handicap for the competitiveness of Europe.

Cray in Japan

As already mentioned, Cray has operated in Japan since 1980. Today, 26 systems are installed, mainly in commercial organizations. These systems are a mixture of Cray-1s, X-MPs, Cray-2s, and Y-MPs. Most of them have now been converted to UNICOS. Relatively few systems have the largest configuration and quite a few X-MPs or Y-MPs exist with only one or two CPUs. There may be two reasons for this. One could be the fact that Cray's prices are considered high, especially given that the systems must be purchased (most domestic systems are

leased) with little or no discount. The other explanation may be that the prime need of the Japanese is to get access to applications that run only on the Cray, without a need for the maximum CPU capacity. A clear need for application access is, for instance, demonstrated by the Japanese car manufacturers that have acquired Cray systems to run an application called PAM-crash for car crash simulation.

In spite of the relatively small penetration of Cray systems in Japan, they are nevertheless considered prestigious trendsetters in the market for several reasons. The Cray systems are architecturally very well balanced, UNICOS is seen as a mature supercomputer operating system and, most importantly, a large number of applications (more than 600) exist for the Cray. With the Cray Y-MP now installed by Tohoku University, which has traditionally used only NEC equipment, Cray may have started to penetrate seriously the academic market.

IBM in Japan

IBM has been present in the Japanese market for a very long time. In the early 1960s, when the Japanese Government decided to react to foreign dominance, IBM controlled about 80% of the market. Although the Japanese have reversed this situation, IBM still plays a very important part in the Japanese computing scene. In 1989 IBM sold equipment worth ¥1.19 trillion (about \$8.5 billion, equivalent to approximately 15% of IBM's world-wide sales).

The commercial companies, in particular, seem to be large IBM customers. It is not unusual to see computer centers with several 3090 systems installed (all running MVS) and huge DASD farms with hundreds of gigabytes. In total it is believed that several hundred 3090 systems exist in Japan. The commercial companies seem to appreciate IBM for its total system integration

and well-balanced systems. IBM is able to offer a wide range of peripherals that go with its mainframes, as well as a huge set of applications on top of MVS, both from IBM and from third-party vendors. As already stated, IBM has not had the same penetration in the scientific market in Japan. There has been no equivalent to the EASI program and the total number of vector facilities is rather limited. The recently announced IBM/9000 series will provide IBM with a more powerful system with which to compete in the future. Each VF should offer a peak performance of 400 MFLOPS.

CURRENT JAPANESE SUPERCOMPUTERS AND MAINFRAMES

This section describes the current offerings from NEC, Fujitsu, and Hitachi. A comparison is made with the previous versions. The Appendix contains the specifications of the supercomputer models discussed.

NEC's SX Series

The SX-3 series is the second full generation of production-level NEC supercomputers. In 1984 NEC announced the SX-1 and SX-2 and started delivery in 1985.

The first two SX-2 systems were domestic deliveries to Osaka University and Sumitomo Trading Company. The SX-2 had multiple pipelines with one set of add and multiply floating-point (FP) units each. With a cycle time of 6 ns, each pipelined floating-point unit could peak at 167 MFLOPS. With four pipelines per unit and two FP units, the peak performance was about 1.3 GFLOPS. Due to limited memory bandwidth and other issues, the sustained performance in benchmark tests was typically less than half the peak value. For some reason the SX-1 had a slightly higher cycle time

than the SX-2 (7 ns). In addition, it had only half the number of pipelines. The maximum execution rate was 570 MFLOPS.

At the end of 1987, NEC improved its supercomputer family with the announcement of the A-series, which gave some improvements to the memory and input/output (I/O) bandwidth. The top model, the SX-2A, had the same theoretical peak performance as the SX-2. A family of lower speed systems included the SX-JA (250 MFLOPS), the SX-1EA (330 MFLOPS), and the SX-1A (665 MFLOPS).

In 1989 NEC announced a rather revolutionary new model with several important changes. New technology was used with logic chips that have the highest density in industry today. The vector cycle time was halved and the number of pipelines was doubled, but most significantly NEC added multiprocessing capability to its new series. The new top of the range currently features four independent arithmetic processors (each with a scalar and a vector processing unit), and NEC has pushed its performance by more than one order of magnitude to an impressive peak of

22 GFLOPS (from 1.33 on the SX-2A). From initial benchmark results, one would deduce that the SX-3 is now the most powerful system in the world.

The logic LSI of the SX-3 has 20,000 gates per chip and a gate switching time delay of 70 ps per gate. This is a major technological jump from what NEC applied in the SX-2 series, namely 1,000 gates and a 250-ps time delay. The packaging consists of multi-chip packages (MCP) that are made of a ceramic substrate upon which the LSIs are mounted directly. A board is 22.5 by 22.5 cm² and can contain a maximum of 100 LSIs. It is water cooled by the cold plate method.

The scalar unit has 128 64-bit registers. It decodes all instructions and runs in parallel to the vector unit. It is a RISC-based design using scalar pipelines to speed up execution. Nevertheless, the cycle time is the full machine cycle (5.8 ns) and peak scalar FLOPS are roughly two orders of magnitude lower than peak vector performance. This fact highlights the need to push applications in the direction of full vectorization in order to exploit the SX-3 at its best. The scalar processor

has a 64-KB cache and a 4-KB instruction stack with 1.6 ns access time. The cache size is no bigger than it was in the SX-2. The processor has a sophisticated branch prediction mechanism built into the instruction stack hardware. The instruction format is either 64-bit with memory addresses included (for load, store, and branch instructions) or 32-bit for arithmetic operations (specifying three registers). Unlike Hitachi and Fujitsu, NEC's basic instruction set is not compatible with that of IBM. The scalar processor supports 64-bit integers directly in native hardware.

The vector processor is equipped (in the largest configuration) with four pipelines integrating four floating-point units (two add and two multiply). The compilers will optimize the vector performance automatically by scheduling vector instructions on all the parallel hardware but will have to be enhanced to cope with parallel execution.

The SX-3 can cope with Cray and IBM floating-point format (in hardware). IEEE formats can be expected in future systems but not in the SX-3. Table 4 is a detailed overview of the various SX-3 models and their corresponding peak performance values.

Table 4. Model Differences for the SX-3 Supercomputer

| SX-3 Model | Arithmetic Processors (AP) | Add/Multiply Pipelined Units | Add/Multiply FP Units | Vector Registers (KB/AP) | Maximum Speed (GFLOPS) |
|------------|----------------------------|------------------------------|-----------------------|--------------------------|------------------------|
| 11 | 1 | 1 | 4 | 36 | 1.37 |
| 12 | 1 | 2 | 4 | 72 | 2.75 |
| 14 | 1 | 4 | 4 | 144 | 5.5 |
| 22 | 2 | 2 | 4 | 72 | 5.5 |
| 24 | 2 | 4 | 4 | 144 | 11 |
| 42 | 4 | 2 | 4 | 72 | 11 |
| 44 | 4 | 4 | 4 | 144 | 22 |

Primary memory was based on 256-Kbit SRAMs with 20 ns access time. NEC has announced that this will be changed to 1-Mbit memory chips in 1991. The maximum memory configuration will then be expanded from 2 GB to 8 GB. The total memory bandwidth is subdivided into two halves (with two processors each) which, in turn, feature one vector store and two vector load paths as well as one scalar load path and one scalar store path. Like its predecessor, the SX-3 is probably unable to offer the memory bandwidth needed to sustain peak performance unless most operands are contained in the vector registers. The current maximum size of the external memory unit (XMU) is 16 GB based on 1-Mbit DRAMs with 70 ns access time. By changing to 4-Mbit DRAMs in 1991, NEC will increase the external memory to 64 GB. This is an incredible memory size. (How many people remember 64 KB as a respectable memory size!) The system allows 8 bytes to be transferred from the XMU to memory per minor clock cycle, giving a transfer speed of 2.75 GB/s.

There can be a maximum of four I/O processors (IOPs), each with a 250-MB/s throughput. The channels can be 3, 6, or 20 MB/s (with a maximum of 64 channels/IOP). High-speed channels operate as eight pairs of 100-MB/s channels directly through direct memory access (DMA). NEC has an agreement with Ultraset and will provide an HPPI interface in 1991.

NEC has started shipping uniprocessor versions of the SX-3 to Europe. The University of Cologne has received

an SX-3/11 and the Dutch Aerospace Lab, NLR, will receive an SX-3/12 in May 1991. The Swiss Government will most likely install a dyadic version in the second half of 1991. Four-processor versions of the SX-3 are not expected before 1992.

Fujitsu's VP Series

The VP-2000 series is the second generation of full production-level Fujitsu supercomputers. In 1977 Fujitsu produced the first supercomputer prototype called the F230-75 APU, which was a pipelined vector processor added to a scalar processor.

In 1983 Fujitsu came out with the VP-200 and VP-100 systems, which later spun off the low-end VP-50 and VP-30 systems. In 1986 came the VP-400 (with twice as many pipelines as the VP-200), and as of mid-1987 the whole family became the E-series with the addition of an extra (multiply-add) pipelined floating-point unit that boosted the performance potential by 50%. Thanks to the flexible range of systems in this generation (VP-30E to VP-400E), and other reasons such as good marketing and a broad range of applications, Fujitsu became the largest domestic supplier with 63 systems.

The VP-2000 family, which was announced in 1989 and has been available since March/April 1990, has a peak performance of 5 GFLOPS.

Fujitsu's design philosophy (like the other Japanese manufacturers) has been centered around the original APU design where the vector processor was a distinctly separate unit from the

scalar unit. Emphasis was put on multiple pipelines with multiple floating-point units. The VP-2000 series is the first Fujitsu supercomputer with multiple scalar or vector processors. The VP-2000 system was initially announced with four vector performance levels (models 2100, 2200, 2400, and 2600) where each level could have either one or two scalar processors (corresponding to a model /10 or a model /20). The VP-2400/40, announced the end of August 1990, doubles the number of processors compared to the VP-2400/20 and will have a peak vector performance similar to the VP-2600.

Table 5 explains the relationship of the Fujitsu models.

Like the other Japanese manufacturers, the model range is basically constructed by removing hardware elements from the top model. Firstly, the pipelines are reduced from four to two and then to one, and finally one of the two sets of add and multiply units is removed. The memory pipes are reduced in a similar fashion.

The logic LSI has 15,000 gates per chip and a propagation delay of 80 ps/gate. This is a very impressive level of integration, although the corresponding NEC figures are slightly better. Both Fujitsu and NEC seem to be at the very leading edge of VLSI today. The very high integration in the VP-2000 series enables the entire scalar processor to sit on just one multilayer glass ceramic board of 61 layers, which allows elimination of off-board signal delays for the processor. The board is 24.5 by 24.5 cm² and can contain a maximum of 144 LSIs.

Table 5. Model Differences for the VP-2000 Series

| VP-2000 Model | Vector Cycle Time (ns) | Vector Processors (VPs) | Scalar Processors | Vector FP Units | Multiply/Add FP Units | Pipelines/VP | Vector Registers Per Scalar Unit (KB) | Maximum Speed (GFLOPS) |
|---------------|------------------------|-------------------------|-------------------|-----------------|-----------------------|--------------|---------------------------------------|------------------------|
| 2100 | 4 | 1 | 2 | 5 | 2 | 1 | 32 | 0.5 |
| 2200 | 4 | 1 | 2 | 7 | 4 | 1 | 32 | 1 |
| 2400/20 | 4 | 1 | 2 | 7 | 4 | 2 | 64 | 2 |
| 2400/40 | 3.2 | 2 | 4 | 7 | 4 | 4 | 64 | 5 |
| 2600 | 3.2 | 1 | 2 | 7 | 4 | 4 | 64 | 5 |

The scalar unit has a cycle time of 6.4 ns and is connected to a 128-KB buffer storage with an access time of 1.6 ns. This very fast logic-and-RAM LSI is built up of 64-Kbit chips with 3,500 gates. The same chips are used for the vector registers.

In Fujitsu's design, the vector processor sits between two scalar processors, which act as instruction processors. The vector processor can be fed from either. Having twice as many scalar processors as vector processors can be seen as an effort to improve the balance between scalar and vector performance. The memory system can be configured with 2 GB of real memory using the latest LSI technology with 35-ns, 1-Mbit SRAM chips. The secondary subsystem unit (SSU) can have up to 8 GB of memory using 1-Mbit DRAM (100-ns) chips, and Fujitsu has declared that it will move to 4-Mbit DRAMs in 1991 to allow second-level memory systems of 32 GB.

Previous machines have been heavily criticized for the lack of memory throughput. The VP-400 series had only one fetch/store path to memory that ran at 4.5 GB/s. This has been improved in the VP-2000 series but is probably not sufficient in all cases (in particular where all operands and the results must be fetched or replaced).

As already stated, Fujitsu has been shipping the new series since April 1990. The first two VP-2600 systems were delivered to the Japanese Atomic Energy Commission (JAERI). Via Siemens several systems have also been imported to Germany. The University of Karlsruhe and the University of Hannover have each installed a VP-2400/10 and Siemens has installed a VP-2200/20 in its VLSI design center. The University of Aachen has a VP-2400/10 on order for February 1991. Amdahl marketed the previous version of the VP systems (after having added MVS support). It has announced that it will not market the VP-2000 series.

Hitachi's S-Series

Hitachi differs from the two other manufacturers in a couple of aspects. Firstly, it does not export its supercomputers, and secondly, the current offering is somewhat out-of-date compared to the latest systems from NEC and Fujitsu. In this article the S-820 is therefore treated less thoroughly than the other systems. Nevertheless, the S-820 should be judged on the technology it represented at first shipment date, and Hitachi should be judged on the technology it possesses in general. It is believed that a new supercomputer from Hitachi will be announced during 1991.

The Appendix summarizes the main characteristics of the two generations of supercomputers manufactured by Hitachi. The S-820 system offers four performance levels (m.20, m.40, m.60, and m.80) corresponding to the number of pipelines per floating-point unit (see Table 6). The lowest model has an 8-ns vector cycle time. The logic LSI has 5,000 gates per chip and a propagation delay of 250 ps/gate. The scalar unit has a cycle time of 8 ns (major cycle time) and is connected to a 256-KB buffer storage with an access time of 4.5 ns. This bipolar RAM is built up of 16-Kbit chips, whereas the faster LSI for the vector registers has 2,500 gates, 6.9-Kbit capacity, and an access time of 2.5 ns.

The memory system can be configured with 512 MB of real memory using a technology with 20-ns, 1-Mbit BiCMOS chips. The extended storage can have up to 12 GB of memory using 1-Mbit DRAM (120-ns) chips.

Hitachi has put great emphasis on a fast memory, although this has meant limiting it to maximum 512 MB. The memory bandwidth (2 words per pipe per vector cycle) is a respectable achievement, but it is not enough to keep all functional units busy (if memory access is needed for each add, multiply, and generated result). The I/O processor supports 64 channels and half of them can be 9-MB optical channels. The total I/O capacity is 288 MB/s.

Table 6. Model Differences for the S-820 Supercomputer

| Model No. | Vector Cycle Time (ns) | Multiply/Add Pipeline Units | Vector Pipeline Units | Pipelines Inside Unit | Vector Registers Per Scalar Unit (KB) | Data Bus (8 B/4 ns) | Maximum Speed (GFLOPS) |
|-----------|------------------------|-----------------------------|-----------------------|-----------------------|---------------------------------------|---------------------|------------------------|
| 20 | 8 | 3 | 5 | 1 | 32 | 1 | 0.375 |
| 40 | 4 | 3 | 5 | 1 | 32 | 2*1 | 0.75 |
| 60 | 4 | 3 | 5 | 2 | 64 | 2*2 | 1.5 |
| 80 | 4 | 3 | 5 | 4 | 128 | 2*4 | 3 |

Japanese Mainframes

As previously described, all three Japanese manufacturers announced new mainframe systems between July and September 1990. As far as NEC and Fujitsu are concerned, their mainframes are based on the scalar processor of their supercomputer, only with a higher level of multiprocessing and a different memory system. The two-level cache is, for instance, one manifestation of this difference. Table 7 lists the latest announcements.

Hitachi and Fujitsu offer their systems also as plug-compatible systems to IBM abroad. Fujitsu offers systems via their 47% share in Amdahl, who licenses the technology and makes the systems compatible, and Hitachi does it via Comparex, Olivetti, and Hitachi Data Systems.

NEC does not offer IBM compatible systems but is expected to announce UNIX support for its ACOS/3800 in the export market (as well as domestically). The MIPS rates are estimates of commercial MIPS. In a scientific environment, the performance is not known, but both the Fujitsu processors and the NEC processors are estimated at about 30 MFLOPS (scalar) for the LINPACK 100 x 100 test.

All three vendors are expected to announce 8-way systems as the maximum configuration of this machine generation.

JAPANESE SYSTEM SOFTWARE AND COMPILERS

Proprietary Systems

As already explained, the Japanese supercomputers originally grew out of the mainframe families. The corresponding operating systems did the same, and since the Japanese domestic operating systems were all inspired by IBM's MVS, these mainframe systems also

invaded the supercomputers. Fujitsu had MSP, Hitachi had VOS3, and NEC had SXOS.

The advantage for domestic installations that possessed both mainframes and supercomputers was the "de facto" compatibility between the two, but both the European and U.S. markets refused to get seriously interested in these systems.

Manufacturers' Involvement with UNIX

With the latest series of supercomputers and mainframes, the Japanese manufacturers have announced a serious interest in UNIX. Fujitsu has had a version of UTS (UTS/M), which it obtained from Amdahl in 1985, available on its mainframes since 1986 (native since 1987). With the announcement of the VP-2000 series, Fujitsu initially announced a VPO (vector processing option) to make UTS/M into a supercomputer operating system, but it has now announced a consolidated UNIX offering for both environments, "UXP/M," which will be based on System V, release 4 and shipped in the middle of 1991. NEC has also announced its version of UNIX, Super-UX, for its supercomputers, not (yet?) for its mainframes. NEC will also ship its UNIX-version in the first half of 1991. Both manufacturers base their systems on AT&T System V and are members of UNIX International. Hitachi has not announced UNIX for its high-end systems but is expected to do so with the announcement of its next supercomputer generation. Hitachi is a member of OSF.

Previously it was speculated that the Japanese market is experiencing a limited growth as far as supercomputers are concerned. This can be interpreted as an additional argument why it is vital for the Japanese manufacturers to offer UNIX to satisfy the export market.

UNIX Usage in Japan

In the domestic market UNIX is available in certain sectors. Workstation systems are almost exclusively based on UNIX. The domestic market leaders are HP/Apollo, SUN, and Sony, all with about 25-30% of the market each. Beyond the workstation segment, Cray has largely converted its customer base from COS to UNICOS. This is, of course, a marginal UNIX penetration seen from a global market perspective, but one should not underestimate Cray's influence as a trendsetter in supercomputer software. Some installations (universities and research centers) run UTS/M as a parallel offering to the domestic MSP system, but with little real emphasis until now. It is therefore believed that the conversion to UNIX in the domestic market in Japan will be relatively slow and that the Japanese manufacturers will initially target their UNIX systems to the export market. This could imply a heavy burden on the first foreign companies as they will have to get involved in debugging and enhancing these versions of UNIX on large systems, in a similar fashion to the very early customers of Cray's UNICOS.

UXP/M and Super-UX

Both NEC and Fujitsu have to repeat what Cray did several years ago, namely, convert UNIX from a time-sharing system to a highly reliable and sophisticated operating system for a supercomputer. The changes that are necessary are rather fundamental: kernel modifications for the detailed support of the architecture, the multiprocessor support, the memory management scheme, the I/O subsystem, the scheduler, etc. A batch system, NQS (network queuing system), has to be integrated and significantly enhanced.

Table 7. Latest Generation of Japanese Mainframes

| Mainframe | Cycle Time (ns) | Maximum CPU Configuration | Commercial MIPS | Delivery |
|----------------|-----------------|---------------------------|-----------------|----------|
| Hitachi M-880 | 8.0 | 4 way | 155 | 4Q90 |
| Fujitsu M-1800 | 6.4 | 8 way | 325 | 3Q91 |
| NEC ACOS/3800 | 5.8 | 6 way | 375 | 3Q91 |

The file system needs modifications both for speed improvements, large file sizes, and complexity. I/O drivers for the full set of peripherals must be integrated. Reliability features need to be added to make sure the system software can keep the machine up all the time. This is no simple task, but a good UNIX implementation has become a requirement for the Japanese manufacturers (at least in the scientific export market).

SUPER-UX will start shipping early in 1991 (release 1.1). It is based on System V, release 3 with many BSD extensions. In addition to the general improvements already mentioned, it will come with a supercomputer file system that is implemented in parallel to the System V file system (SVFS). It will offer support for Ethernet, FDDI, and HPPI networks including NSC's DX and Ultratnet.

UXP/M is in a similar situation. Its predecessor UTS/M + VPO (vector processing option) started shipping in the fourth quarter of 1990. The file system has been greatly enhanced with several options such as asynchronous I/O, bufferless I/O, high-speed I/O via secondary memory, etc. Furthermore, NQS, memory management, reliability improvements for hardware and software, as well as improved systems management facilities have had to be integrated.

Assemblers and Compilers

First some words about assemblers. Interestingly enough, neither NEC nor Fujitsu offered the assembler to its customers on previous supercomputer systems. Hitachi did offer it after domestic pressure from the user community. Today the assembler is made available both for the SX-3 and the VP-2000 series. For code optimization and complex coding in certain areas, assembly programming can still be an important asset in maximizing the use of a supercomputer.

Most supercomputer programs, however, rely on a highly optimized FORTRAN compiler. In the past the Japanese FORTRAN compilers have been optimized for single-task vector processing. With the introduction of multiprocessing hardware a new dimension of parallel execution has been opened for the supercomputer users, but at the cost of complex additions to the compiler itself. Language extensions for user-controlled parallelism as well as automatic parallelization techniques have to be added. Both macrotasking at the subroutine level and microtasking at the loop or statement level must be dealt with. NEC and Fujitsu will start offering these capabilities as of 1991, but an additional period for refining the techniques in light of the experience with real-life applications in the field must be included.

Application Software

It is beyond the scope of this article to provide an in-depth review of the application software available on the Japanese platforms. Given the ongoing effort to offer UNIX as the preferred operating system at least abroad, it is believed that such a survey should be undertaken when the UNIX offering is mature and the porting of applications has been carried out on a massive level.

The Japanese manufacturers are extremely keen to be able to offer the same applications on their platforms as Cray. For this reason both NEC and Fujitsu have established competence centers and collaborations in the United States. In certain cases there will be political pressure to stop applications being ported to Japanese platforms. This is the case today with PAM-crash, which is a vital applications package for automobile crash simulation and certification.

SUMMARY AND CONCLUSIONS

The Japanese Computer Industry

This article has tried to demonstrate that the Japanese seem to be succeeding in what is thought to have been the two legs of their national computing strategy:

- Create computing solutions (hardware and software) that will satisfy the domestic demands as much as possible.
- Enhance or adapt these solutions so that they will compete successfully in the export market.

The Japanese have largely fulfilled the first goal by acquiring a share of about 80% (revenue-based) of the domestic market, whereas in the 1960s they achieved a mere 20%. It is interesting to note that this success is based on a very broadly based computer industry as demonstrated in the section on Japanese electronics companies.

On the export market Fujitsu and Hitachi have had an initial strategy to operate as plug-compatible manufacturers (PCMs) to IBM. This has allowed them to penetrate both the American market via Amdahl and HDS (Hitachi Data Systems) as well as the European market via HDS, Compax (Siemens/BASF), Olivetti, and Amdahl. As long as this continues to be a lucrative market, these companies are expected to stay put. Nevertheless, the general trend to UNIX and open systems is believed to gradually move the emphasis away from proprietary systems. The Japanese manufacturers have clearly understood the importance of this shift and should offer complete UNIX systems for both mainframes and supercomputers within the near future (Fujitsu has already announced its UXP/M for both environments). To secure the success of this effort the Japanese companies have all established centers in Europe or the United States to ease porting operations and capture new trends and evolutions in the rapidly moving UNIX area.

Japanese component technology has been state of the art for some time already. Whether one considers chip density, switching speed, or other technological factors, the Japanese compete

successfully with everybody else in the world. With the latest series of integrated mainframes or supercomputers, the Japanese have also demonstrated that they are now strong players who want to act as market leaders and not as complacent followers any longer. They have reached the stage where their integrated products have the same complexity in terms of multiprocessing or memory subsystems as their competition. Their strategy is now to offer these hardware systems with open system software to a world-wide market.

To create a balanced view of the situation, it must be kept in mind that some of the hardware and software features described in this article are not yet fully available. A year or two may still be needed by the Japanese manufacturers to be able to offer their latest hardware systems, in their largest configurations, with a fully developed and debugged UNIX system and a full range of applications.

Future Evolution

In the near future the Japanese will continue to enhance their systems to improve their competitiveness in the market place. By 1993 they are expected to have the same proportion as the Americans of the world-wide computer market (about 42% each). NEC, Hitachi, and Fujitsu should all by then be selling mainframes and supercomputers with solid UNIX operating systems and a broad spectrum of applications. Follow-on models of the existing systems can be expected, either as new families or as upgrades within the existing families. New players in the high-end computer market can also be expected. Matsushita has already announced its intention to compete in the supercomputer market in the future.

Beyond today's systems the Japanese are evaluating several approaches to improving their products. Silicon-based improvements are being pursued, and

Hitachi has already announced a laboratory version of its 64-Mbit DRAM. Memories should therefore become larger and larger with the advances in memory technology. All manufacturers will pursue the race for lower cycle times (approaching the "magic" 1-ns cycle). Because of inherent limitations of silicon chips, this race could bring out innovative new technologies such as Ga-As or Josephson junctions, both of which have already been explored inside the Japanese research laboratories for quite some time. Integration into commercial products is believed to depend more on what the competitors can achieve than anything else.

Fujitsu has, for instance, developed the HEMT (high electron mobility transistor), which is a variant of the Ga-As technology with promising features both in terms of reduced heat dissipation and greatly improved switching time. The company is already producing 64-KB memory chips based on HEMT and should offer integrated circuits in the near future.

Although traditional architectures will continue to dominate the market for the next few years, the Japanese are also seriously interested in other architectural approaches. Massively parallel systems are believed to be the next evolutionary step in the sophistication of their systems.

Implications for Europe

One of the purposes of this article was to understand the implications for Europe of the current strength of the Japanese computer manufacturers. Unlike the Japanese, the Europeans have not managed to build up an internal computer industry that has sufficient strength to compete with the Americans. Europe has, therefore, been a faithful acquirer of American mainframes and supercomputers (with the notable exception of a few Japanese systems).

In 1993 Europe will be the biggest united market in the world and vital to every large computer manufacturer that wants to succeed in the long term. For the Old World it is critical to anticipate the implications of this privileged position. After this study (the author has also been involved with American computer manufacturers for the last 20 years), it is believed that Europe should initiate a policy based on the following principles:

- Adopt an immediate strategy of encouraging a strong and healthy competition in the European market place between the Americans and the Japanese computer manufacturers. This could lead to lower prices as well as better and more varied software and hardware offerings. Manufacturers should also be told that Europe expects supplementary benefits in terms of local investment in factories and research and development laboratories, which would bring additional employment opportunities and tax money to our communities. This strategy should also ensure that Europe becomes as well equipped with supercomputers as Japan (or the United States for that matter) and therefore maintains European competitiveness.
- Build up a strong software industry as rapidly as possible. This industry should profit from the open systems penetration and build portable application packages that will satisfy not only European demands but will also allow European software products to compete successfully on a world-wide basis. Europe has strong traditions in software and, although the Americans are also very strong software builders, we can probably profit from the fact that our demands are more complex and diversified than those of the United States. How many times have we experienced American

software products that do not cope with the intricate production environments in Europe? Since software is currently also the weak point in Japan's computer strategy, we would have an excellent chance of providing products for their systems both domestically and abroad. This does, of course, presuppose that we become "truly" European in our activities. If we focus solely on regional demands and pursue only local market opportunities, we will not achieve this goal. On the other hand, this strategy should not require the existence of huge companies like the Japanese electronics giants. We can encourage small and dynamic software houses to help us achieve this goal.

- Master the aspects of system integration. The future of computing will be very complex. Computer manufacturers will bring innumerable platforms to the market from hand-held microcomputers to teraflop supercomputers. In addition, vast numbers of peripherals, multiple connectivity options, and evolving network protocols will all be elements that will contribute to a high level of complexity in our data processing environments, and the only realistic option is to assume that the issue will not get simpler over time. Computer users, however, will demand applications and systems that give a unified view of distributed software and databases. In the author's opinion, it is therefore much more important to master the aspects of system integration than to produce the individual hardware elements. Nevertheless, it assumes broad-minded companies that can evaluate the advantages of individual computing elements and produce both a vision and follow up the vision with a solution. The broadness of the vision should not be the limits of Europe in 1993; it should

be the limits of the globe. Japan and its activities must absolutely be an integral part of it on par with the United States.

In contrast, the author is rather skeptical about direct European competition with the American and Japanese electronics giants as far as hardware systems are concerned. Siemens will, we hope, continue to be present on the list of the world's largest companies, but up until now it has in no way been able to initiate a computer hardware strategy analogous to that of the Japanese companies discussed in this article. On the contrary, the supercomputers sold by Siemens are obtained directly from Fujitsu, and the large mainframes offered by Comparex (a joint Siemens/BASF company) are Hitachi systems. There will probably be niche opportunities, and Europe should continually try to explore the possibility of producing systems where added value is given to an integrated computer product even if the components are largely bought off the shelf in Japan or the United States.

In summary, up until now, computers were mainly supplied to Europe by the United States. In the future they should be acquired from both the United States and Japan. Rather than hoping for Europe to become a computer supplier of the same caliber as these two, we should exploit fully this competitive situation as well as the opportunities for providing value-added software solutions and highly qualified system integration.

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Sverre Jarp graduated from the Technical University of Trondheim in 1971 with a degree in theoretical physics. In 1972 he did his military service working for the Norwegian Defense Research Institute. In 1973 he worked for Data-Logic, Oslo, in the area of commercial data processing, mainly assembler programming on IBM/360 systems. Since 1974 he has been working in the Data Handling Division at CERN (European Laboratory for Particle Physics), first as CDC Systems Programmer, then as IBM Systems Programmer with particular responsibility for performance monitoring and system configurations. Between 1983 and 1989 Mr. Jarp was in charge of the IBM systems programming covering VM and MVS on large IBM and IBM-compatible (Fujitsu) mainframes. Since June 1989 he has been in charge of all central system software in CN. This covers the operating systems on the central IBM, DEC, and Cray computers; workstation systems like Apollos and DEC stations; as well as all implementations of the ORACLE database products available on most hardware platforms at CERN. Between 1983 and 1990 Mr. Jarp was active in SHARE Europe, one of the European IBM User Groups. He was active on the Executive Board of this association from 1985 and was president from 1987-88.

Appendix

SUPERCOMPUTERS IN JAPAN

Table A-1. Main Features of the Last Two Generations of NEC Supercomputers

| Feature | SX-2A | SX-3 |
|-------------------------------|---------------------|--------------------|
| Scalar processors | 1 | 4 |
| Scalar cycle time (ns) | 6 | 5.8 |
| Vector processors | 1 | 4 |
| Vector cycle time (ns) | 6 | 2.9 |
| Gates in logic | 1,000 | 20,000 |
| Switching time (ps) | 250 | 70 |
| Cache technology/chip density | 1 Kbit bipolar. RAM | 40 Kbit + 7K gates |
| Cache access time (ns) | 3.5 | 1.6 |
| Cache size (KB/CPU) | 64 | 64 |
| Vector registers (KB/CPU) | 80 | 144 |
| Floating-point (FP) units | 2 (mult/add) | 4 (2 mult/add) |
| Pipelines per FP unit | 4 | 4 |
| Maximum GFLOPS | 1.3 | 22 |
| Memory interleave | 512 way | 1,024 way |
| Memory transfer rate (GB/s) | 11 | 80 |
| Main memory technology | 256 Kbit SRAM | 256 Kbit SRAM |
| Memory access time (ns) | 40 | 20 |
| Maximum memory (GB) | 1 | 2 |
| Second-level memory | 256 Kbit SRAM | 1 Mbit DRAM |
| Access time (ns) | | 70 |
| Maximum memory (GB) | 8 | 16 |
| Transfer rate to main (GB/s) | 1.3 | 2.75 |
| I/O units | 1 | 4 |
| Total I/O throughput | 192 MB/s | 1 GB/s |
| Initial shipment date | Jun 88 | Sep 90 |

Table A-2. Main Features of the Last Two Generations of Fujitsu Supercomputers

| Feature | VP-400E | VP-2600 |
|-------------------------------|---------------|----------------|
| Scalar processors | 1 | 2 |
| Scalar cycle time (ns) | 14 | 6.4 |
| Vector processors | 1 | 1 |
| Vector cycle time (ns) | 7 | 3.2 |
| Gates in logic | 400/1,300 | 15,000 |
| Switching time (ps) | 350 | 80 |
| Cache technology/chip density | 4 Kbit | 64 Kbit |
| Cache access time (ns) | 5.5 | 1.6 |
| Cache size (KB/CPU) | 64 | 2*128 |
| Vector registers (KB/CPU) | 128 | 2*128 |
| Floating-point (FP) units | 3 (add+M-add) | 4 (2 mult-add) |
| Pipelines per FP unit | 4 | 4 |
| Maximum GFLOPS | 1.7 | 5 |
| Memory interleave | 128/256 way | 512 way |
| Memory transfer rate (GB/s) | 4.5 | 20 |
| Main memory technology | 256 Kbit SRAM | 1 Mbit SRAM |
| Memory access time (ns) | 55 | 35 |
| Maximum memory (GB) | 256 MB | 2 GB |
| Second-level memory | 256 Kbit SRAM | 1 Mbit DRAM |
| Access time (ns) | | 100 |
| Maximum memory (GB) | 768 MB | 8 GB |
| Transfer rate to main (GB/s) | 4.5 | 10 |
| I/O units | 1 | 1 |
| Total I/O throughput | 96 MB/s | 1 GB/s |
| Initial shipment date | Dec 87 | Apr 90 |

Table A-3. Main Features of Two Generations of Hitachi Supercomputers

| Feature | S-810/20 | S-820/80 |
|-------------------------------|---------------|------------------------|
| Scalar processors | 1 | 1 |
| Scalar cycle time (ns) | 14 | 8 |
| Vector processors | 1 | 1 |
| Vector cycle time (ns) | 7 | 4 |
| Gates in logic | 550/1,500 | 2,000/5,000 |
| Switching time (ps) | 350/450 | 200/250 |
| Cache technology/chip density | 1 Kbit | 6,900 Kbit+2,500 gates |
| Cache access time (ns) | 4.5 | 4.5 |
| Cache size (KB/CPU) | 256 | 256 |
| Vector reg access time (ns) | 4.5 | 2.5 |
| Vector registers (KB/CPU) | 64 | 128 |
| Floating-point (FP) units | 3 | 3 (add&L+add/mult) |
| Pipelines per FP unit | 2 | 4 |
| Maximum GFLOPS | 0.63 | 3 (2 if unchained ops) |
| Memory interleave | | 256 |
| Memory transfer rate (GB/s) | | 16 |
| Main memory technology | 16 Kbit CMOS | 64 Kbit BiCMOS |
| Memory access time (ns) | 40 | 20 |
| Maximum memory (GB) | 256 | 512 |
| Second-level memory | 256 Kbit DRAM | 1 Mbit DRAM |
| Access time (ns) | | 120 |
| Maximum memory (GB) | 3 | 12 |
| Transfer rate to main (GB/s) | 1 GB/s | 2 GB/s |
| I/O units | 1 (32 ch.) | 1 (64 ch.) |
| Total I/O throughput | 96 | 288 |
| Initial shipment date | Dec 83 | Jan 88 |

Table A-4. Known Cray Supercomputers Installed in Japan

[26 installed systems, sorted by installation name,
3 Y-MP2Es on order, as of December 1990.]

| Customer Name | System | Date | Prefecture | Sector |
|--------------------------|------------|-------|------------|-----------------|
| Aichi Inst of Tech | X-MP/14se | 88/03 | Aichi | Priv univ |
| Asahi Chemical | Y-MP2E/116 | 91/03 | Shizuoka | Chemistry |
| Century Research Corp. | Cray-1 | 80/02 | Tokyo | Service bureau |
| | X-MP/18 | 88/01 | Kanagawa | |
| Daihatsu-Kogyo | Y-MP2/216 | 90/07 | Osaka | Automobile |
| Honda R&D | Y-MP8/364 | 90/09 | Tochigi | Automobile |
| | X-MP/14 | 87/03 | | |
| Isuzu Motor | Y-MP2E/232 | 91/04 | Kanagawa | Automobile |
| Mazda | X-MP/216 | 88/12 | Hiroshima | Automobile |
| | Y-MP2E/232 | 91/02 | | |
| MITI/AIST | X-MP/216 | 88/02 | Ibaraki | Govt & natl lab |
| Mitsubishi Elec Lab | Y-MP4/132 | 89/10 | Osaka | Conglomerate |
| Mitsubishi Heavy Ind | X-MP/116 | 90/05 | Hyogo | Heavy industry |
| Mitsubishi Motor Corp. | Y-MP4/116 | 89/10 | Aichi | Automobile |
| Mitsubishi Res Inst | Y-MP2/116 | 89/11 | Tokyo | Research |
| Mitsubishi Research Inst | Cray-1 | 80/07 | Tokyo | Service bureau |
| NTT | X-MP/22 | 84/08 | Tokyo | Conglomerate |
| | Cray-2/4 | 87/12 | | |
| Nissan | X-MP/12 | 86/05 | Kanagawa | Automobile |
| | X-MPEA/432 | 88/10 | | |
| | Y-MP8/664 | 90/08 | | |
| Recruit | X-MP/216 | 86/12 | Kanagawa | Service bureau |
| | X-MP/18 | 88/02 | Osaka | Service center |
| Sumitomo Chemical | X-MP/116se | 89/09 | Osaka | Chemistry |
| Tohoku Univ | Y-MP8/4128 | 90/12 | Miyagi | Natl univ |
| Toshiba | X-MP/22 | 85/02 | Kanagawa | Conglomerate |
| | Y-MP8/232 | 90/03 | | |
| Toyota | X-MP/116 | 88/08 | Aichi | Automobile |
| | Y-MP8/232 | 90/03 | | |

Table A-5. ETA Supercomputers in Japan

[2 systems, sorted by installation name, as of December 1990.]

| Customer Name | System | Date | Prefecture | Sector |
|--------------------|----------|-------|------------|-----------|
| Meiji Univ | ETA10-P | 89/04 | Kanagawa | Priv univ |
| Tokyo Inst of Tech | ETA10-E8 | 88/05 | Tokyo | Natl univ |

Table A-6. Fujitsu Supercomputers in Japan

[59 out of 63 systems, sorted by installation name,
internal Fujitsu systems not included, as of December 1990.]

| Customer Name | System | Date | Prefecture | Sector |
|------------------------------------|------------|-------|------------|-----------------|
| Advantest | VP-50 | 85/11 | Tokyo | Conglomerate |
| Air Force | VP-50 | 87/08 | Tokyo | Govt & natl lab |
| Asahi Kogaku PENTAX | VP-30E | 88/10 | Tokyo | Optical |
| Chiyoda Info Service | VP-50 | 86/04 | Tokyo | Chemistry? |
| Chuo Univ | VP-30E | 87/10 | Tokyo | Priv univ |
| Computer Tech Integ | VP-2400/20 | 90/08 | | Service bureau |
| Daikin Air Conditioner | VP-100 | 87/03 | Osaka | Mechanical |
| Diesel Kiki | VP-30E | 89/02 | Tokyo | Automobile |
| Electric Power Lab | VP-50E | 87/09 | Tokyo | Govt & natl lab |
| Fuji Electric | VP-50 | 85/12 | Kanagawa | Conglomerate |
| Fuji Electro-Chemical | VP-50E | 88/11 | Tokyo | Conglomerate |
| Hazama-gumi | VP-30E | 88/10 | Tokyo | Construction |
| ICFD (Fluid Dynamics) | VP-200 | 86/04 | Tokyo | Research |
| | VP-400E | 89/03 | | |
| Inst Nuclear Fusion | VP-200 | 83/12 | Ibaraki | Govt & natl lab |
| | VP-200E | 88/03 | | |
| Inst Space Aeronautic S. | VP-200E | 88/04 | Tokyo | Govt & natl lab |
| Ishikawajima-Harima | VP-50 | 86/05 | Kanagawa | Heavy industry |
| JAERI (Atomic Energy) ^a | VP-2600/10 | 90/04 | Ibaraki | Govt & natl lab |
| Kanagawa Univ | VP-30E | 87/08 | Kanagawa | Priv univ |
| Kansai Univ | VP-50E | 88/08 | Osaka | Priv univ |
| Kawasaki Steel | VP-50 | 86/01 | Chiba | Metal |
| Keio Univ | VP-50E | 89/08 | Kanagawa | Priv univ |
| KHI | VP-50 | 87/06 | Kawasaki | Mechanical |
| Kobe Steel | VP-200 | 87/06 | Hyogo | Metal |
| Kodak Japan | VP-50E | 88/11 | Tokyo | Chemistry |
| Kyoto Univ | VP-400E | 87/08 | Kyoto | Natl univ |
| | VP-2600/10 | 90/09 | | |
| Kyushu Univ | VP-200 | 87/08 | Fukuoka | Natl univ |
| Matsushita | VP-30E | 87/08 | Osaka | Conglomerate |
| | VP-100 | 85/12 | | |
| Mitsubishi Kasei | VP-50 | 86/07 | Kanagawa | Chemistry |
| Nagoya Univ | VP-200E | 88/03 | Aichi | Natl univ |
| NAL (Space Tech) | VP-400E | 86/12 | Tokyo | Govt & natl lab |
| | VP-2600/10 | 90/10 | | |
| Natl Astro Observatory | VP-200E | 89/11 | Tokyo | Govt & natl lab |
| Nihon Univ | VP-30E | 87/12 | Chiba | Priv univ |
| Nikko Shoken | VP-2200/10 | 90/12 | | Financial |
| Nippon Kokan (NKK) | VP-50 | 87/08 | Kawasaki | Metal |
| Nippon Univ ^a | VP-30E | 87/12 | Chiba | Priv univ |
| NTT | VP-50 | 86/05 | Kanagawa | Conglomerate |

continued

Table A-6. Continued

| Customer Name | System | Date | Prefecture | Sector |
|------------------------|------------|-------|------------|----------------|
| Olympus | VP-50 | 86/05 | Tokyo | Mechanical |
| Osaka Inst of Tech | VP-30E | 88/12 | Osaka | Priv univ |
| Pacific Consulting | VP-30E | 89/01 | Tokyo | Consulting |
| Recruit | VP-200 | 86/06 | Tokyo | Service bureau |
| | VP-400 | | | |
| Sharp | VP-50 | 86/04 | Osaka | Conglomerate |
| Shibaura Inst of Tech | VP-30E | 87/10 | Tokyo | Priv univ |
| Shimizu | VP-50 | 86/06 | Tokyo | Construction |
| Shionogi | VP-30 | 87/05 | Osaka | Chemistry |
| Sony | VP-2200/10 | 90/11 | Kanagawa | Electronics |
| Suukeikaku | VP-30E | 88/10 | Tokyo | Math program |
| Tokyo Electronics Univ | VP-100E | 89/10 | Tokyo | Priv univ |
| Tokyo Univ | VP-100 | 86/11 | Tokyo | Natl univ |
| Toray | VP-30 | 87/08 | Tokyo | Chemistry |
| Toyota | VP-100 | 85/08 | Aichi | Automobile |
| | VP-100E | 88/04 | | |

^aTwo of the same supercomputers were installed at one time.

Table A-7. Hitachi Supercomputers in Japan

[18 systems, sorted by installation name,
internal Hitachi systems not included, as of December 1990.]

| Customer Name | System | Date | Prefecture | Sector |
|-------------------------|----------|-------|------------|-----------------|
| Bridgestone | S-810/5 | 87/05 | Tokyo | Chemistry |
| Canon | S-820/60 | 89/10 | Kanagawa | Conglomerate |
| Dainippon Print | S-810/5 | 88/02 | Tokyo | Conglomerate |
| Hokkaido Univ | S-820/80 | 89/02 | Hokkaido | Natl univ |
| ICFD (Fluid Dynamics) | S-820/80 | 88/10 | Tokyo | Research |
| IMS (Molecular Science) | S-820/80 | 88/01 | Ibaraki | Govt & natl lab |
| JIP | S-810/5 | 87/05 | Chiba | Center |
| KEK (High Energy Lab) | S-820/80 | 89/03 | Ibaraki | Govt & natl lab |
| Metrology Agency | S-810/20 | 87/11 | Tokyo | Govt & natl lab |
| MRI (Meteorology) | S-810/10 | 85/11 | Ibaraki | Govt & natl lab |
| NDK Nippon El Comp | S-810/10 | 87/02 | | Center |
| Nihon Univ | S-820/40 | 89/06 | Chiba | Priv univ |
| Nissan Diesel | S-810/5 | 87/04 | Saitama | Automobile |
| Olubis | S-810/5 | 88/02 | Shizuoka | Center |
| Suzuki Motors | S-820/60 | 88/12 | Shizuoka | Automobile |
| Tokyo Univ | S-820/80 | 88/01 | Tokyo | Natl univ |
| Toyo Gum | S-810/5 | 87/10 | Tokyo | Chemistry |
| Yamaichi Shoken | S-820/60 | 89/04 | Tokyo | Finance |

Table A-8. NEC Supercomputers in Japan

[18 installed systems, sorted by installation name,
internal NEC systems not included, as of December 1990.]

| Customer Name | System | Date | Prefecture | Sector |
|------------------------|--------|-------|------------|-----------------|
| Aoyama Univ | SX-1EA | 88/10 | Tokyo | Priv univ |
| Computer Engineer Ctr | SX-1A | 88/12 | | Service bureau |
| Daiwa Shoken | SX-1A | 89/08 | Tokyo | Financial |
| ICFD (Fluid Dynamics) | SX-2 | 87/05 | Tokyo | Research |
| Japan Dev Construction | SX-JA | 90/03 | | Construction |
| Japan Railway | SX-JA | 88/11 | Tokyo | Govt & natl lab |
| Kumagai | SX-1 | 89/08 | Tokyo | Construction |
| Mazda | SX-2A | 89/09 | Hiroshima | Automobile |
| Obayashi Corp. | SX-1EA | 88/06 | Tokyo | Construction |
| Okayama Univ | SX-1E | 87/05 | Okayama | Natl univ |
| Osaka Univ | SX-2 | 88/01 | Osaka | Natl univ |
| Port & Harbor Research | SX-1E | 87/12 | Kanagawa | Govt & natl lab |
| Recruit | SX-2A | 88/10 | Tokyo | Service bureau |
| Sumitomo Metal | SX-2 | 88/03 | Osaka | Metal industry |
| Tohoku Univ | SX-1 | 86/03 | Miyagi | Natl univ |
| | SX-2A | 88/12 | | |
| Tokai Univ | SX-1E | 86/09 | Kanagawa | Priv univ |
| | SX-1 | 89/09 | | |

WELDING TECHNOLOGY IN JAPAN AND KOREA

Drs. Glen R. Edwards and S. Liu of the Center for Welding and Joining Research of the Colorado School of Mines participated in the First Japan-U.S. Symposium on Advances in Welding Metallurgy in Yokohama, Japan, 12-13 June 1990, and presented a paper titled "Recent Developments in HSLA Steel Welding." The meeting was cosponsored by the American Welding Society, the Japan Welding Society, and the Japan Welding Engineering Society. Following the symposium, Edwards and Liu visited the R&D Laboratories II of the Nippon Steel Corporation in Sagami-hara, where technical discussions were held with Nippon Steel researchers. Liu continued on to visit the Welding Division of Kobe Steel Company (KOBELCO) in Fujisawa, the Welding and Production Engineering Department and the Welding Research Institute of Osaka University in Ibaraki, KOBELCO in West Kobe, and Kawasaki Heavy Industries in Kobe. Liu also visited the Pohang Iron and Steel Company (POSCO) in Pohang, Korea, where he made presentations and held technical discussions with Korean researchers. This report describes the highlights of the visits.

by Glen R. Edwards and Stephen Liu

FIRST JAPAN-U.S. SYMPOSIUM ON ADVANCES IN WELDING METALLURGY

The program for the First Japan-U.S. Symposium on Advances in Welding Metallurgy consisted of 16 invited presentations, 8 from the United States and 8 from Japan, covering topics that include the welding of advanced materials, high strength low alloy (HSLA) steels, stainless steels, etc. The complete program was presented first in San Francisco, California, and then in Yokohama, Japan.

Much of the Japanese work presented at the conference exemplified the patient "improvement by persistent iteration" approach that has characterized Japanese research for many years. A good example of this can be found in Yurioka's work. Dr. Nobutaka Yurioka

has, over the past 8 years, patiently modified the available formulation for carbon equivalent for steels common to arc welding. His most recent results include the effects of cooling rate and accurately predict heat-affected zone (HAZ) hardness in microalloyed steels, where boron levels of 4 to 6 ppm can be important. While not fundamental research, these efforts are very useful in predicting weldability and illustrate the attention to detail that is the secret to the success of the Japanese in competing for the materials to be used in welded structures around the world. It is important to note that research such as the carbon equivalent work of Yurioka is financed by Japanese industry and Government. Similar work in the United States is impossible to fund; American industry typically does not

have the patience for such work, and Federal funding agencies do not view this type of research sufficiently fundamental and advanced.

In contrast to the meeting held in San Francisco, California, where a modest attendance of 65 participants occurred, over 140 welding professionals participated in Yokohama, Japan. To ensure a successful meeting and quorum, the Japan Welding Society and Japan Welding Engineer Society approached their industrial and corporate members and requested that each member company send a certain number of participants, according to the size of the corporation. Intimate cooperation (industry-professional society) such as this is very unusual in the United States and may serve as an example for future professional or scientific events.

The Yokohama meeting was well organized, with ample time for questions and discussion. The meeting took place at the International Conference Center, an excellent facility with superior acoustics and seating arrangements. A large U-shaped seating configuration allowed each attendee to have an excellent opportunity to participate. The Yokohama meeting was also well publicized, including television and newspaper coverage. These reports in the press emphasized the aspect of free exchange of information between the United States and Japan. Our observations, however, were that the Japanese presentations did not include "leading edge" results, but rather contained only updated versions of developments already well published in Western journals.

NIPPON STEEL CORPORATION R&D LABORATORIES II

Nippon Steel has three research and development (R&D) facilities. R&D Laboratories I, located in the Hiyoshi district, has six laboratories performing chemicals research, materials research, material characterization research, and future and frontier field research. The processing of materials such as ceramics, electronic materials (gold wire, condensers, etc.), shape memory alloys, intermetallics, coal tar, and petrochemicals is being investigated. Computational analysis, advanced thermodynamics, and computer software development are the major foci of the future and frontier field research laboratory. R&D Laboratories II, soon to be moved from Sagami-hara to the Kimitsu Works, is product oriented and carries out investigations on plate, bar, rod, sheet, coil, and tubular products. Stainless steel and titanium are the other materials of concern. The surface treatment laboratory deals with galvanizing, oxide coating, and organic

coating research. R&D Laboratories III in Higashida is iron and steel making oriented and performs research in the areas of direct reduction for iron making, steel making, direct solidification, forming, near net shape processing, heat treating, and the thermal and energy aspects of iron and steel processing.

A meeting was held at R&D Laboratories II with Dr. Nobutaka Yurioka, manager of the Joining Technology Research Laboratory, and a group of Nippon Steel researchers. Also present were Mr. Y. Horii and Mr. S. Ohkita, both well known in HSLA welding and weld metal microstructural refinement. In this meeting, Dr. Stephen Liu summarized the research programs at the Center for Welding and Joining Research at the Colorado School of Mines. Two Nippon Steel researchers also presented their results on stainless steel research (Dr. Tadao Ogawa) and solidification modeling (Mr. Toshihiko Koseki).

Twenty percent of the Nippon Steel researchers at R&D Laboratories II hold Ph.D. or equivalent degrees. A majority of the researchers (over 50%) majored in metallurgy and chemistry, indicating the emphasis at Nippon Steel on metals and materials research. Forty percent of the researchers are between 40 to 49 years of age, with approximately 15 to 25 years of research experience. It was pointed out during the meeting that the ratio of researchers to technicians at R&D Laboratories II has been approximately one for the past 5 years and that the ratio of administrative staff to researchers decreased from 14% to 11% in the same period. This is a good indication of the commitment of Nippon Steel to research by providing adequate support services to the researchers. Additionally, continuous improvement of the research force is sought by sending young researchers overseas to pursue advanced degrees.

Research work at the Nippon Steel Joining Laboratory is very focused and applied. Studies are conducted in terms of specific alloys and procedures, mostly to improve the competitive edge for Nippon Steel. Several areas of interest are noteworthy. Materials that contain functional gradients such as the protective coating of a jet engine component are being developed using a low pressure plasma spray (LPPS) technique. The gradual chemical composition transition in these coatings serves to prevent discontinuities in physical and mechanical properties. Coating (galvanized and electrolytically coated) research at Nippon Steel can be exemplified by the composition-controlled electrical resistance welding (ERW) project, which has the purpose of improving electrode life. With certain combinations of coatings, an electrode can perform 5,000 spot welds, while if bare and coated sheets are alternatively welded, the electrode can only survive 1,000 spots. Concerning process application, a dc resistance welding machine has been developed to weld steel cans at a speed of 400 cans per minute. It would require a 5-kW laser to perform the same work on 6-mm-thick steel sheets.

A typical example of the ingenuity of Japanese corporations is the small welding robot developed at Nippon Steel to perform arc welding during building construction. Instead of a conventional, full size off-the-shelf robot, a small "gadget-like" robot with simple mechanical sensors was built to sense the joints and perform the welding. The instrument was inexpensive, cleverly designed, and extremely portable, so that it could assist the welder in making ordinary weldments during high rise construction. The reduced cost and versatility of this robot make Nippon Steel extremely competitive in service contracts.

The Joining Laboratory also plans to scale up their electrode plant for

producing flux-cored stainless steel welding electrodes using the Oerlikon process. This is an attempt to gain some market from other established consumable manufacturers such as Kobe Steel, Ltd. Nippon Steel's decision of manufacturing flux-cored electrodes seems to indicate that the process is well accepted in Japan and gaining popularity among Japanese industrialists. Since the United States is the only other major supplier of flux-cored welding consumables, American manufacturers should pay close attention to this development. Electroslag welding, abandoned in the United States for its extremely high heat input, is being investigated and applied in high carbon steel rail welding. The main emphasis is on the design of new fillers that will match the low melting point of the high carbon base material and avoid HAZ liquation and hot cracking problems.

Nippon Steel R&D Laboratories II is very well equipped and has some unique equipment. A mechanical testing machine of 8,000-ton capacity is available for tension, compression, and fatigue testing of large members. Several large thermomechanical testing systems to perform weld simulation or deformation studies are also available. These systems can induction heat samples from room temperature to 1,400 °C in 4 seconds. For the characterization of inclusions and precipitates, a low energy electron diffraction (LEED) unit is present. The laboratory is also equipped with a one million volt transmission electron microscope for examining the fine structure of metals and materials. A computer-aided micro-analyzer was developed by Nippon Steel to assist in the determination of internal structures of inclusions. Cold and hot isostatic pressing (CIP and HIP) equipment is also available.

KOBE STEEL, LTD. (KOBELCO), WELDING DIVISION, FUJISAWA PLANT

Kobe Steel, Ltd. (KOBELCO) has approximately 50% of the Japanese market in welding consumables, ranging from covered electrodes and semi-automatic welding wires to flux and wire combinations for automatic welding. In addition, the Welding Division of KOBELCO also manufactures advanced welding robots and welding power sources.

The Fujisawa Plant is the main KOBELCO production unit for the manufacturing of flux-cored wires, welding robots, welding power sources, and equipment. Welding research and development is also located at Fujisawa with approximately 200 people, of which 120 are research staff. Most of the remaining 80 are support staff, including laboratory technicians and administrative personnel. The Welding Division has good analytical capabilities, from the determination of flux behavior to microanalysis of inclusions. Thermomechanical simulators are also available to perform laboratory weld testing.

A meeting was held with Dr. Yoshiya Sakai, the general manager of the Technical (Research) Department; Mr. Fumito Yoshino, the planning manager; and Mr. Yutaka Nishikawa, a senior research engineer. In this meeting, it was indicated that flux-cored arc welding is becoming more popular in Japan, particularly welding with smaller diameter electrodes. Kobe also expects the fine wire flux-cored welding, together with pulsed power sources, to become more significant in production in the coming years. It is interesting to mention that a major welding equipment manufacturer in the United States had investigated the flux-cored pulsed-arc welding process. Without achieving

much success in 1 year, the company decided to cancel the program. Short term research, driven by immediate return, must be carefully balanced by long range programs.

In the formulation of fluxes and coatings for electrodes, KOBELCO is probably one of the few companies that uses results of arc observation and metal transfer mode studies. The effects of different ingredients on metal transfer mode are examined to minimize spatter in metal active gas (MAG) welding. The results gathered from the detailed study of droplet transfer at different current waveforms in pulsed-arc welding and the effect of shielding gas are also used to improve welding power source design. The KOBELCO Sensarc power source, a result of such research, can monitor the arc signal once every 10 μ s, thereby helping to control weld spatter and penetration.

American welding equipment and consumables manufacturers need to adapt quickly to modern techniques and research approaches in electrode design. More stringent design requirements for critical applications and demand for higher quality consumables result in almost customized products. The trial-and-error approach is too costly and unpredictable to support the development of large corporations in international competition.

In the area of welding robots and automation, KOBELCO is actively developing unmanned welding processes for unmanned factories. Systems with integrated technologies such as off-line teaching or off-line programming that separate the robot teaching process from the job site and that increase the arc-on time and productivity of a factory are also developed. Computer software and personal computer (PC) links that interface welding robots to microcomputers are also research topics at KOBELCO Welding Division.

OSAKA UNIVERSITY

Department of Welding and Production Engineering

Osaka University is world renowned for its welding engineering education and research. The Department of Welding and Production Engineering is organized by Chairs (or "Laboratories"). Each Chair (or "Laboratory") is directed by a professor; under this professor, one associate professor and two Ph.D. level research associates conduct research work. Each Chair has its own laboratories, equipped to perform research and teaching. Cooperative research across Chairs is, however, not common. The eight Chairs in the Welding and Production Engineering Department are as follows: fundamentals in materials processing for welding and production, liquid state materials processing for welding and production, solid state materials processing for welding and production, structural design for welding and production, processes and machines for welding and production, systems engineering for welding and production, materials mechanics and structural behavior for welding and production, and reliability assessment for welding and production. It is important to notice that systems engineering and reliability assessment are, in the United States, engineering disciplines traditionally found in industrial engineering or operations research curricula. In Osaka University, the welding engineering students are taught early in their program that industrial production must be integrated. Procedure, quality, and worker involvement determine the efficiency and productivity of a corporation.

A brief meeting was held with Prof. Dr. Hiroshi Maruo, head of the department and the "Fundamentals in Materials Processing for Welding and Production" Chair. His areas of expertise

are laser cutting and surface modification by chemical vapor deposition of materials, including plain and high carbon steels, pulsed-arc welding, and nonspatter CO₂ welding. His research represents a balance of new processes and conventional technology, with emphasis on both advanced processes such as plasma processing and more established processes such as arc welding.

A second meeting was held with Prof. Dr. Yoshikuni Nakao, the "Solid State Materials Processing for Welding and Production" Chair; Prof. Dr. Kazutoshi Nishimoto, associate professor; and Dr. Kenji Shinozaki, the research associate. The major research themes for this group are insert metal development for transient liquid phase (TLP) bonding, filler materials development for heat-resisting alloys, joining of surface-modified materials, and joining of intermetallic materials.

In the area of ceramic-to-metal joining, the mechanical integrity of the interface and the interfacial reactions are the two major research concerns. Insert materials are developed to match the coefficient of thermal expansion of the base material such that no cracking would occur during cooling. Along with characterization of the interface, Nakao's group is also modeling the stress distribution along the interface using finite element methods (FEM). However, according to Nakao, the general interest in ceramic-to-metal joining has decreased and the volume of research support has also declined, even in the more popular aluminum nitride-copper system. No specific reasons were provided; the difficulty in integrating the technology into engineering systems may be the reason.

Diffusion bonding of titanium aluminide and TLP bonding of oxide dispersion strengthened (ODS) alloys such as MA956 are other research projects in progress. Investigations are also being carried out to formulate filler metals of optimal composition for the

joining of iron-based heat-resistant alloys. Ion plating to modify surface composition of alloys for bonding is also a topic of considerable interest. Laser glazing of nickel-based alloys such as Inconel 625, Hastelloy X, and Incoloy 800 and ceramic coating on stainless steel are other innovative technologies in development.

Most studies at the Welding and Production Engineering Department are industrially oriented. A majority of the research projects are cosponsored by the Japanese Government and industries. Similar to the work in American universities, Japanese thesis research is systematic and detailed. The differences are the duration of graduate study, typically longer than in the United States, and the duration of each research program, which also is longer than that of U.S. programs.

The "Solid State Materials Processing for Welding and Production" Chair is well equipped with some unique research facilities. Physical vapor deposition equipment with rf activation source and the capability of depositing 200 microns per hour is available. A new scanning tunneling electron microscope (STEM) from Digital Instrument was recently installed for surface analysis. To produce insert materials for brazing, particularly those alloys that form intermetallic compounds, a spin melting facility is available for amorphous ribbon production. In addition to the industrial CO₂ lasers, a high energy excimer laser (ultraviolet radiation of wavelength equal to 248 nm) with Ar-KrF, Ar-ArF, or Ar-XeF is also used to investigate laser activated physical vapor deposition of ceramic materials.

Welding Research Institute

The Welding Research Institute is organized in divisions and centers. The divisions and centers interact and collaborate in research with several

academic departments of the university, for example, Welding and Production Engineering, Naval Architecture, and Civil Engineering.

A meeting was held with Prof. Dr. Akira Matsunawa, Chair of the "Laser and High Performance Materials Processing" Laboratory, and Dr. Seiji Katayama, research instructor. Their major research interests are beam-matter interactions in laser materials processing, laser process stabilization by pulse shaping, laser nitriding/boronizing/carburizing, ceramics coating by laser chemical vapor deposition, ceramics and metal coating by laser physical vapor deposition, production of ultrafine metallic (30 to 40 nm) and ceramic (50 to 60 nm) particles by laser evaporation method, laser rapid solidification, laser surface amorphization, and modeling of heat and mass transfer in fusion welding.

Unique research equipment includes a high density electron beam welder (600 kV) and a 1-MeV transmission electron microscope (TEM).

The Welding Research Institute is a national facility that can be accessed by all Japanese industries and universities. It employs approximately 30 researchers, bringing the total Osaka University welding effort to approximately 60 researchers. This number is small when compared with the 700 to 1,000 engineers at Paton Institute in the Soviet Union or the 550 staff members of the Welding Institute in the United Kingdom. However, the Osaka University welding group is very productive and visible, with very active participation in international conferences and symposia. The strong Government and institutional support and excellent infrastructure towards research are undoubtedly the major reasons for their success. Even while under tremendous budget constraint, the U.S. Government must remain conscious of the fact that universities are the sources of future talent and that university research is the only means to prepare

them for the challenge. Appropriate research funding and environment should be allocated and provided consistently for such a purpose. As an example, the Osaka Welding Research Institute receives funds from the Japanese Government to promote multiple year international exchange programs. Scholars from overseas are invited to jointly investigate the welding and joining sciences. This benefits most the Japanese host institutions because of the new concepts and thinking that these scientists bring.

KOBE STEEL, LTD. (KOBELCO), SEISHIN INDUSTRIAL PARK

KOBELCO has a broad R&D structure, including activities in both conventional and nonconventional areas. Conventional research focuses on ferrous and nonferrous alloys, machinery design and construction, and manufacturing processes, including welding, joining, and cutting. Nonconventional research is conducted in the fields of advanced materials (intermetallics, polymers, and composites), electronic and magnetic materials (superconductors), biotechnology, and cryogenics.

The KOBELCO R&D effort is concentrated in five locations: (1) materials and engineering in West Kobe, Japan; (2) biotechnology in Tsukuba, Japan; (3) thin films in Research Triangle Park, North Carolina, U.S.; (4) polymers and composites in Surrey, U.K.; and (5) electronic materials near Stanford University in California, U.S. (laboratory to be established shortly). Site selection is based on local expertise and cost of research. KOBELCO believes that their association with experts will result in new developments, leading edge technology, and market share.

Currently, the laboratories at Tsukuba, North Carolina, and Surrey are all functioning. The Seishin

Industrial Park (West Kobe) in construction is also well along schedule, with the superconductor and cryogenics technology center, mechanical engineering research laboratory, and electronics research laboratory in place and operating. All other research departments and laboratories currently at the Kobe office, including the materials research laboratory, will be relocated by 1991 to Seishin Park.

Dr. K. Ikeda, ex-director of R&D and currently a senior advisor for the KOBELCO Board of Directors, was the contact and guide during the Seishin Park visit. Advanced techniques and products of higher added values are the focal points of KOBELCO research. In fact, the diversification of interest of KOBELCO, from the traditional iron and steel technology, can be testified by the fact that the company now produces 60% of the magnetic materials (for hard disk storage) marketed in the whole world. New intermetallic materials and amorphous materials are other topics of research. In the case of intermetallic materials, a Japanese Government-Industries-Universities program coordinated by the Ministry of International Trade and Industry (MITI) was initiated 5 years ago and resulted in potential commercial applications in the near future. This and other MITI coordinated programs in different strategic areas demonstrate that Japan has long range research planning that is not in place in the United States.

A tour in the clean room and the electronic materials facility showed the following materials being investigated: superalloy and rapidly solidified metal powders for turbine disks, fiber-reinforced metals, shape memory alloys, thin film diamond, and amorphous wire. Equipment for surface finishing processes such as ion implantation, plasma spray, and microwave plasma chemical vapor deposition (CVD) and other advanced fabrication processes such as hot isostatic pressing (HIP), fine

crystal high pressure crystallization, superconducting wire welding using electron beam (EB), microfabrication by excimer lasers, etc. is available. For magnetic properties characterization, equipment based on the Kerr effect for domain structure determination is available. Equipment such as a micro-ion beam apparatus for the evaluation of optical and electronic properties of materials is also available. Surface characterization (reaction products, surface thickness, and roughness) studies are well equipped with a STEM, ellipsometer, diamond profilometer, and high resolution scanning electron microscope (SEM). The SEM has the capability of low accelerating voltage (variable down to 1 kV) and can be operated without the need for carbon coating of most materials.

Mechanical engineering research areas include robotics; computer integrated manufacturing (CIM); industrial machineries and process design; fluid, thermal, and combustion technologies; and dynamic and acoustic technologies. Unique research facilities include a small water tunnel for fluid flow characterization and a large sound room. The sound room is used for acoustic impedance measurement of new materials and devices, sound field analysis, and sound psychological evaluation. The most significant research effort related to welding and joining is, however, the development of a system for detecting flaws in bonded interfaces. The KOBELCO system is capable of examining ultrasonically a sandwich of three materials and two interfaces.

One particularly important characteristic of KOBELCO is their vision and practice in investing in education and R&D. Not only does KOBELCO send their researchers to the United States and other countries for graduate level training and postdoctoral sabbaticals, but the corporation also recently financed 40% of a total cost of ¥3.45B to establish a branch campus of St.

Catherine College, Oxford University, in Kobe. World renowned specialists will come to Japan, sponsored by KOBELCO, to work closely with Japanese in the area of economics and administration. In terms of research commitment, KOBELCO has a generous \$110M/yr (¥15B/yr) research budget. A valuable lesson could be learned from this progressive company. While the United States still maintains a viable market in thin films technology and electronic materials, KOBELCO is willing to invest for the future to the extent of establishing research facilities in the United States where expertise in these areas is centralized. Can the United States maintain its market in the face of such dedicated investment?

KAWASAKI HEAVY INDUSTRIES, OSAKA

Akashi Technical Institute is the research organization of Kawasaki Heavy Industries and consists of laboratories in the areas of cryogenics, materials, corrosion, thermal technology, biotechnology, space technology, welding and materials processing, and opto-engineering.

The welding and materials processing laboratory has a total of approximately 90 workers: 30 research engineers, 30 technicians, and 30 supporting staff (for example, x-ray facility, etc.). A meeting was held at the Kobe Works with Dr. Shigetomo Matsui, senior manager of the welding group, and his engineers. Dr. Matsui is also a member of the international committee of the Japan Welding Society that promotes international collaboration. Most of the scientists and researchers contacted during this trip expressed the same desire for more open information exchange.

Kawasaki Heavy Industries has a large number of contracts around the world and many of them are related to welding and joining. Examples of Kawasaki products are: New York

subway cars, inspection equipment for the Japanese Shinkansen ("bullet") trains, the center and forward fuselage and main wing support ribs of many Boeing jets, self-cooling turbine generators, helicopters, submersible rigs, underwater mobiles, submarines, and jet foils. Currently, the most challenging project is the tunnel boring machine that Kawasaki provides to the U.K.-France underwater tunnel construction project. All boring equipment and earth removal and support systems are contained in a 10-m-diameter shell.

Typical of all Japanese industrial research, emphasis is given to projects that can be directly applicable to manufacturing and production situations. Some of the major Kawasaki achievements are:

- (1) Abrasive wear-resistant double-walled pipes fabricated by the ring heat shrink (RHS) method. An induction coil heats the moving pipe, leading to local expansion and yielding, followed by rapid cooling under the water spray cooling unit. With restraint deformation and shrinkage of diameter, Kawasaki can produce straight and bent double-walled pipes, in T- and Y-joints. Pipes of dissimilar materials such as a ceramic inner pipe and a carbon steel outer pipe for flue discharge can also be processed.
- (2) Water cutting systems. A high pressure water jet (pressure of 2,200 to 4,000 kgf/cm²) with or without abrasives was developed to produce high precision cutting in all materials. The system is capable of free shape and blind cutting, and parts (metallic and nonmetallic) processed this way have excellent finish with no chips or burrs. Extremely high cutting speed can be achieved. The system can be interfaced with computers for integrated manufacturing.

The concept of water jet cutting is not new; it has been used in the mining industries for years. In fact, the process was originally developed at the Mining Engineering Department of the Colorado School of Mines. Kawasaki recognized the potential of such a process and further adapted it into a marketable system for manufacturing. Thorough engineering thinking and hard work are the strongest characteristics of the Japanese materials technologists.

Other research areas of the welding group include automation and robotization of the metal inert gas (MIG) and tungsten inert gas (TIG) welding processes, weld cracking prevention, and new heat sources. The welding group also has an electron beam welding machine, an automatic ultrasound testing (UT) system, a low pressure plasma spray unit, gas tungsten arc (GTA) narrow gap welding equipment, a diffusion bonding machine, and surface treatment processes.

Like other Japanese corporations, Kawasaki also invests heavily in personnel training. They also sponsor the Kawasaki Chair at the Massachusetts Institute of Technology.

POHANG IRON AND STEEL COMPANY (POSCO), KOREA

Pohang Steel Works

POSCO is the largest and most modern single integrated steel plant in Southeast Asia. The company produces approximately 15 million tons of steel yearly (9.5 million tons at the Pohang Works and 5.5 million tons at the Kwangyang Works).

Most of the equipment at the Pohang Works, purchased from Japan and Europe, is only a few years old. The most efficient and specialized units visited at the Pohang Works were the blast furnaces for pig iron production and the controlled rolling mill for thermomechanical control processed

(TMCP) steel production. With a production of 9,000 tons per day, blast furnace #4 at POSCO is not the largest in the world (there are furnaces in Japan with records of well above 10,000 tons of pig iron per day); however, it has the capability of coke fine injection, preheating and oxygen-enriching the blast, and providing a blast temperature over 1,200 °C. For the designed hearth capacity, #4 can be considered one of the most efficient blast furnaces in the world. According to Dr. Rhee, vice president of the Iron and Steels Division at the Research Institute of Industrial Science and Technology (RIST) and a blast furnace specialist, the goal of the company is to eventually eliminate solid coke feed from the raw material charge.

The TMCP line is an enclosed, box-like unit of total chamber length of 30 meters, with compressed air and water mist injection capability. The cooling of incoming plates from 900 to 500 °C is accomplished in approximately 220 s. This results in a controllable cooling rate of 4.5 to 23 °C/s. Depending on the type of product, the amount of cold water and air blast can be programmed differently with the rolling schedule to provide the specific microstructure and mechanical properties desired. POSCO has gained some experience in processing TMCP plates with this equipment.

Research Institute of Industrial Science and Technology (RIST)

In 1987, the Technical Research Institute of POSCO was restructured to become the Research Institute of Industrial Science and Technology (RIST), with the aim of developing advanced iron and steel technologies and future-oriented strategic technologies for POSCO. RIST is composed of five divisions and one center. The five divisions are: Iron and Steel Division (the largest division), New Materials

Division, Science and Engineering Division, Administrative Division, and Management and Economics Division. Technical Service and Technical Information constitute a support facility for the five divisions.

Currently, the institute employs approximately 390 researchers, with more than 150 possessing a Ph.D. or equivalent degree. An additional 200 technicians and 110 administrative personnel staff the institute. Similar to many Japanese research organizations, the ratio of the number of support staff to the number of researchers is also high, indicating the level of support that researchers receive in performing investigations.

Several meetings were held with Prof. Dr. Chang-Hee Rhee, vice president of the Iron and Steel Division; Dr. Ho-Cheon Yoo, head of the Welding Products Laboratory; and other welding researchers. Welding is a department of the Iron and Steel Division, with approximately 30 researchers working in the areas of welding metallurgy, welding processes, and other joining processes. Research activities concentrate on stainless steels, low carbon steels, and high strength steels. However, the researchers of RIST also cover technical assistance and customer service. Consistent with the world-wide advanced materials thrust, some ceramic-to-metal bonding work is also being initiated.

The welding department has excellent facilities in terms of welding and weld simulation with two thermomechanical simulators. The institute has excellent microanalytical facilities such as STEM, electron spectroscopy, LEED, and auger spectroscopy. Special emphasis has been placed in the materials area, particularly, biomedical, electromagnetic, and organic and inorganic materials.

The motto of "resources are limited, creativity is unlimited" helps to illustrate the eagerness and desire of

improvement and growth of POSCO. Despite the more severe competition from other Pacific Rim countries and the gradual deterioration of the Korean economy, POSCO and RIST have been able to recruit new people and purchase new equipment. Nevertheless, comparing POSCO to many Japanese steel companies, it is clear that product quality is still a severe problem (as commented by some researchers). Advances in new materials research are still lagging, and Korea is apparently still years behind the current achievement of Japan.

FINAL COMMENTS

Japanese industries indeed hold different philosophy and ethics. All the meetings are highly professional, with all minor details considered. Guides are provided in many cases to bring the visitors to the meeting place and punctuality is astounding. Meeting schedules are provided at arrival and the meetings are timed precisely. Japanese researchers are upbeat and loyal to their company. It is not unusual for a researcher to work additional hours every day without ever seeking extra compensation. On the other hand, Japanese companies are also loyal to the workers, providing good work environment and stability for professional growth. The employer-employee relationship is company-centered but with mutual trust.

Advanced materials and technology (superconductors, cryogenic materials, electronic materials, intermetallics, ceramics, polymers, composites,

coating technology, and microfabrication) are the leading research areas in Japan. Most activities are coordinated and sponsored by MITI. Five-year research plans are established and tasks divided among the industrial and university participants. Depending on the development or the success of the projects, these projects are renewed or phased out. High strength steel welding was for over 10 years one of the topics investigated. Intermetallic materials research is close to the end with good prospects for commercial products. The Government-Industry-University research triangle is clearly effective in Japan and is the driving force for Japanese success in technological innovation. With the support of the Government, the universities can develop the leading expertise, and the industries can provide the technological innovation and application. As a result, Japan is reaping what it sowed and cultivated during years of careful education, research planning, and execution of technology transfer. It is important that the United States proceed cautiously in short and long range planning and decide which are the strategic technological areas where America should exercise leadership. A balance between basic scientific research (long range) and technological innovation (short range) must be maintained to improve American competitiveness in modern manufacturing industries. Patience and commitment of funding agencies, together with persistence, hard work, and improved support of education of American scientists and engineers, are the "secret" ingredients of future success.

Glen Edwards is currently the director of the Center for Welding and Joining Research and a professor, both at the Colorado School of Mines (CSM). He received his Met. E. from CSM in 1961, his M.S. in materials science from the University of New Mexico in 1967, and his Ph.D. in materials science and engineering from Stanford University in 1971. Prior to CSM, he was on the staff at both Los Alamos National Laboratory and the Naval Postgraduate School in Monterey, California. Professor Edwards is an active member of the American Society for Metals (ASM) International, American Institute for Metallurgical Engineering (AIME) (TMS), American Welding Society (AWS), and the International Institute of Welding. He currently serves as the U.S. delegate for Commission IX, International Institute of Welding; as a Joining Division Council Committee member, ASM International; as president of the ASM Rocky Mountain Chapter; and as a Technical Papers committee member, AWS. Professor Edwards is an active researcher in physical metallurgy and materials joining and has contributed over 80 publications to the science and engineering literature. Honors and awards to Professor Edwards include: Fellow, ASM International; Warren F. Savage Award, Adams Memorial Award, and R.D. Thomas Memorial Award, AWS; Amoco Foundation Teaching Award, CSM; and President's Award, Rocky Mountain Chapter, ASM.

Stephen Liu is an associate professor in the Department of Metallurgical and Materials Engineering at the Colorado School of Mines. He received a B.Sc. (1976) and M.Sc. (1979) in metallurgical engineering from the Escola de Engenharia da Universidade Federal de Minas Gerais, Brazil, and a Ph.D. (1984) in metallurgical engineering from CSM. From 1984 to 1987 he was an assistant professor in welding and joining in the Department of Industrial and Management Systems Engineering at Pennsylvania State University. He joined the staff at CSM in 1987 as an assistant professor in metallurgical engineering. Dr. Liu's research interests are in fusion welding processes, high speed electroslag welding, welding metallurgy, welding fluxes and pyrometallurgical concerns, high temperature materials brazing, ceramic-to-metal joining, phase stability and transformations, engineering materials behavior and selection, and failure analysis. He is a member of a number of professional societies including ASM, AIME, and the American Society of Mechanical Engineers.

OCEANOGRAPHY IN INDONESIA

Oceanographic research plays a prominent role in Indonesia's development plans, both in the civilian and military sectors. But because of a lack of trained oceanographers, Indonesia has recognized the need to establish cooperative programs with other countries to draw upon their scientific talents and training opportunities. This article describes Indonesia's present and projected oceanographic research topics and its plans for cooperative projects.

by David Evans

Indonesia, the fifth most populous country in the world, with a significant supply of diverse natural resources including petroleum, is composed of over 13,000 islands and 735,000 square miles of water. It has a tradition of depending on the sea; until recently, it was also the largest freshwater aquaculture nation in the world. As a developing country, it is not surprising that marine studies play a prominent role in its development plans, which range from fisheries to energy development to mineral recovery to offshore petroleum drilling. Its crucial position between the Pacific and Indian Oceans, between Japan and China and India and the Mideast, also makes its seas of potential strategic interest. The great number of islands, straits, passages, and seas greatly complicates that interest. This dual importance, civil and military, sharply focuses the joint activities of the Indonesian defense establishment in economic as well as security activities. Indeed, the military has explicit missions in both sectors, and military members serve on many nominally civilian agencies.

Although acknowledged as a high priority area, there are few trained oceanographers in Indonesia; all of those with advanced degrees have been educated abroad. (Unlike many other developing countries, Indonesia has a

nearly 100% return rate on its foreign trained students.) Estimates are that there are fewer than 100 marine scientists, with less than 10 in physical and chemical oceanography. Most of those are burdened with government positions as well as scientific research responsibilities and teaching. An ambitious program funded by the International Development Bank has begun to establish higher education in oceanography at six Indonesian institutions. For the near term, however, the Indonesians recognize a need to establish cooperative programs with other countries in order to draw upon their scientific talents and training opportunities.

Major new resources have been obtained in the form of three modern research vessels provided by France during 1989 and 1990. The *Baruna Jaya I, II, and III* are equipped for general oceanography, hydrographic surveys, and marine geology and geophysics, respectively. They measure about 60 meters and displace approximately 300 gross tons, making them comparable to the popular *Oceanus* class in the United States. Although still needing some equipment, they are fitted with winches, conducting cables, computers, etc. The *Baruna Jaya I* has a Guildline CTD system, and final arrangements are being made for the installation of a Krup-Atlas high resolution bathymetric

mapping system for the *Baruna Jaya III*. This is the same system selected by Lamont-Doherty for use on their new vessel, *Bernier*. Plans call for the fleet to increase by three to nine more ships by the year 2000. The ships carry Indonesian Navy officers and crew but typically have civilian scientific parties. They are assigned to the civilian Agency for the Assessment and Application of Technology (BPPT is the Indonesian acronym), not to the military. Scheduling is accomplished by an interagency marine science committee headed jointly by Prof. Zen of BPPT and Dr. Aprilani of the Indonesian National Science Foundation (LIPI).

Not unlike the situation in many developing countries, nearly all research in Indonesia is "applied." This seems especially true in the marine sciences. There is no identifiable group of "pure scholars" as there is in the U.S. university community; rather, the scientists are explicitly focussed on problems relating to national development. There is an explicit national strategy for scientific research that emphasizes the eastern portion of the country and the sea. Under that strategy, oceanography is identified as a high priority research area with three prioritized principal topics: resource development, including aquaculture, minerals, and energy; pollution monitoring; and global climate

change. The latter topic derives from the concern about possible changes in sea level in the long term and the impact of El Ninos in the shorter term. El Nino strongly modulates the local climate and changes patterns of monsoonal rainfall dramatically, affecting the success of crops such as rice.

It is the third topic that provides the best possibility for developing cooperative programs with the mainstream U.S. academic community. Collaborative agreements are presently in place with the French, the Australians, and the Germans. The French have recently made measurements of water properties, currents, and species diversity. The Australian program is part of an ASEAN-Australian joint program to measure sea level and oceanic throughflow. Tide gauges have been in place for 3 years, with reporting and analysis to continue for at least 4 more years. Current meter measurements in Makassa Strait are planned for next year. In addition, under this third priority topic, the Indonesians have recently begun planning a cooperative effort with the Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) program and have appointed Dr. Ilahude from LIPI to be their representative to the World Ocean Circulation Experiment (WOCE). In the case of TOGA-COARE, the participation may be largely in meteorology but may include the use of one of the *Baruna Jaya* vessels. No plans have yet been articulated for active participation in WOCE, but discussions are underway. Efforts are currently being

pursued through the National Oceanic and Atmospheric Administration (NOAA) for possible U.S.-Indonesian cooperation on a number of climate-related problems based on a seven-topic proposal made by the Indonesians to the United States last December.

A number of generalizations have emerged from the discussions with Indonesian leaders. Most cooperative programs will require assistance from the foreign partners. The Indonesians will expect both financial and training help as a part of any agreement. An important distinction is made between marine science research and "mapping." The latter is very sensitive for both military reasons and economic resource development. The data are viewed as classified and are carefully guarded. While the United States makes similar distinctions, the definitions are not coincident. For example, unless very narrowly constrained, CTD measurements tend to be viewed in the same light as hydrographic measurements and are therefore liable to classification. The importance of this point cannot be overstated when discussing possible programs. As a general principle, the Indonesians prefer to have all data subject to possible classification, and thus greatly constrain the degree to which civilian agencies in the United States may participate. Their strong interest in becoming involved in the international global change research program may have an impact on their implementation of the data policy; it will certainly force a more careful evaluation of the difference between mapping and research.

Indonesian waters play a critical role in ocean circulation studies and are of importance to biological and geological oceanography as well. Marine biology is moderately well advanced with a number of small coastal laboratories. Marine geology and geophysics have attracted significant attention due to their relevance to petroleum and mineral exploration and development. In view of the possibility of change in data policies, combined with scientific opportunity, it may well be worth the effort to establish cooperative research programs in the future.

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THE U.S. NAVY AND OCEANOGRAPHY IN INDIA

To help encourage collaboration between India and the United States, the Office of Naval Research (ONR) arranged for Prof. Walter Munk of the Scripps Institution of Oceanography to give a series of lectures in India during November 1990. This article describes the present and projected oceanographic research efforts in India supported by ONR and India's participation in Prof. Munk's Heard Island Experiment.

by Bernard J. Zahuranec

The Office of Naval Research (ONR) has supported basic research projects in India for many years. Virtually all of these have been special foreign currency (SFC) projects in oceanic biology funded from accounts of rupees owned by the United States in India. Since these SFC accounts are separate and apart from the normal budget appropriations, they offered a means to support basic research on marine problems in the Indian Ocean, an area poorly known but of increasing strategic importance on the world scene. All research projects are conducted jointly with U.S. collaborators.

About 6 years ago, ONR activities in India began to increase, first with a major grant to the Central Drug Research Institute in Lucknow to study bioactive substances from the Indian Ocean, then with sponsorship of two major Indo-U.S. conferences: in 1984 in Aurangabad on benthic biology of the Indian Ocean and in 1989 in Goa on marine biodeterioration in the Indian Ocean. Proceedings volumes have been published from both conferences. In addition to these marine science efforts, about 4 years ago, a number of activities started in physical and material sciences, so that now these outnumber

the marine science efforts in both number of projects and total funding level.

At present, ONR marine science projects in India include the concluding phase of the marine bioactive substances project as well as three projects in marine biodeterioration at the National Institute of Oceanography (NIO) in Goa. These latter are being conducted in conjunction with several academic institutions in India as well as in collaboration with U.S. scientists.

Obviously, these constitute a very tiny fraction of the total marine science effort in India: probably considerably less than 1%. On the other hand, they are a substantial fraction of the Indian efforts in the specialized areas of marine bioactive substances and marine biodeterioration. For the Indian side, they offer the opportunity for collaboration with U.S. scientists conducting some of the most advanced research and using some of the most advanced techniques in these areas. For the U.S. side, they offer access to Indian Ocean organisms and research problems.

Oceanographic or marine research in India has long been a sensitive area, probably primarily because of national defense considerations. This has

extended to data exchanges and restrictions on collaboration, even where there are no demonstrable national security issues. However, there are indications that these restrictions may be eased in the near future. It is because of this as well as for several other reasons that we anticipate the opportunity that collaborative research between U.S. and Indian oceanographers may begin to increase in the near future. To help encourage collaboration, we arranged for Prof. Walter Munk of the Scripps Institution of Oceanography to give a series of lectures in India during November 1990.

A positive step in the direction of oceanographic collaboration is that the National Institute of Oceanography and the Department of Ocean Development are both enthusiastic supporters of Indian participation in the Heard Island Experiment. This experiment, a concept that originated with Prof. Munk, is a feasibility study to test whether long range low frequency acoustic transmissions can be detected well enough over very long distances in the ocean so that they may have utility as an "acoustic thermometer," a means to measure whether and how much the oceans are warming through climate changes due

to the greenhouse effect. During that recent visit to India, Prof. Munk discussed the specifics of Indian participation in the Heard Island Experiment with them.

The Indians propose to deploy their oceanographic vessel *ORV Sagar Kanya* off the southwest coast of India for the duration of the experiment: from 24 January through 06 February 1991. A U.S. scientist from Scripps Institution of Oceanography will be onboard as well as acoustic listening equipment shipped ahead of his arrival.

At about the same time, 14-16 January, NIO will host a major international conference on oceanography of the Indian Ocean. A large contingent of more than 30 U.S. oceanographers, largely ONR grantees, will be sent by ONR. The opportunity to interact with a broad spectrum of Indian oceanographers may result in a number of collaborative research proposals to study the oceanography of the Indian Ocean.

In such collaborative oceanographic research, there is likely to be special emphasis on the Arabian Sea. It is an area of genuine and widespread scientific interest because of the physical and biological dynamics brought about by the monsoon forcing. Preliminary studies indicate that the conditions are so extreme that this system is almost unique on the planet. It offers the opportunity for laboratory-like experiments on the processes that occur as the summer monsoon winds begin and start to drive the physical dynamics. This, in turn, controls the biological productivity and the entire food chain that culminates in the fisheries of that region.

Furthermore, this Arabian Sea monsoonal forcing system was repeatedly identified by Indian oceanographers and science administrators as one of overriding concern to India over the next decade. The monsoon rains have long been recognized for

their importance to Indian agriculture, and improving their prediction has been a long term goal. But in recent years, there has been increased recognition of the importance of the air-sea interaction processes in controlling the monsoon winds and attendant rains. Thus, it may be expected that a major thrust of Indian oceanographic research will be concerned with the Arabian Sea monsoon system from mathematical modeling through validation, focusing on field studies of the processes involved.

In conjunction with his lecture tour in India, Prof. Munk and the accompanying U.S. team met with Prof. V.K. Gaur, Secretary of the Department of Ocean Development (DOD), to get an appreciation for both the present DOD program and its potential directions over the next 5 years and beyond. Presently, the department has four operational programs and many research and development (R&D) programs. The four operational programs are: (1) the National Ocean Information Systems (NOIS), which is an internal communication network connecting some 13 organizations plus the coordinating headquarters in Delhi; (2) the Marine Information Service, a service to provide marine information such as maps of sea surface temperature of potential fishing grounds, coastal bathymetric data, etc. to the user community including fisherman, the general public, and any government agencies; (3) the Marine Environmental Studies Program, in which 11 different institutes are involved largely with marine pollution problems; and (4) a program for Monitoring and Modeling of Sea-Level Variations, which includes tide gauges at 10 sites and has obvious implications for coastal zone management.

The seven major R&D programs of the Department are: (1) Antarctic Research, (2) Deep Sea Polymetallic (Manganese) Nodules, (3) Living and Nonliving Resource Exploration and

Assessment, (4) Coastal Zone and Island Development, (5) Marine Instrumentation and Systems, (6) Specialized Manpower for Marine R&D, and (7) Policy and Law Relating to the Global Commons (especially polymetallic nodules).

Over the next decade, a number of these and other thrusts may be expected in Indian oceanographic research. Studies will undoubtedly continue on polymetallic nodules but with increased emphasis on two aspects related to the feasibility of their exploitation: (1) the economics of the system and (2) the environmental impacts of mining them. Related to this, in a sense, will be continued baseline studies on the mapping and processes occurring in the Exclusive Economic Zone (EEZ) and the nearshore coastal and island regions of the Andaman and Nicobar Islands to the east of India and the Lakshadweep Islands to the west. Undoubtedly, geophysical exploration for hydrocarbon deposits will continue to be an important part of this research. There will also be continued efforts to use underwater acoustic tomography and other remote sensing techniques for synopticity.

It also appears that Antarctic research will take on increased importance over the next decade as evidenced by plans for the establishment of a new Institute for Antarctic Research in Goa. Up to now, these activities, including operation of the permanent Indian Antarctic station, have largely been under the purview of NIO. The establishment of this new institute will consolidate and focus Indian efforts in Antarctica.

In addition to these areas that may be considered specific research areas, there are indications that the next 5 to 10 years will see increased emphasis in India on what may be considered infrastructure or support efforts. These efforts will include consolidation of networks

for information and data exchange of a variety of oceanographic contexts. Also mentioned as a concern by several individuals was the ever-present problem of the training and education of young, new oceanographers to carry on the research efforts. This ranges from increasing the interest of young students in the oceans to the postgraduate training of oceanographers in the latest advanced research techniques.

Overall, our discussions concerning the present state and future directions of oceanographic research in India resulted in a number of insights, but none especially earth-shaking. Individual scientists, as may be expected, discussed individual personal research interests and goals. But as a whole, Indian oceanographic research concerns and goals were remarkably similar to those of the United States given the climatic, cultural, and environmental differences. Perhaps greater progress toward reaching such goals will come through collaborative efforts between oceanographers of India and other countries when potential mutual benefits are apparent.

Bernard J. Zahuranec has been a scientific officer in the Oceanic Biology Program at ONR since 1973. He is a biological oceanographer specializing in the zoogeography and systematics of mesopelagic fish. He has long been involved in the development and administration of ONR research projects in India and Pakistan. Dr. Zahuranec received a B.S. in zoology in 1961 from Ohio University, an M.S. in biological oceanography in 1967 from the University of California at San Diego/Scripps Institution of Oceanography, and a Ph.D. in biological science in 1980 from George Washington University. He is a member of the American Association for the Advancement of Science, the American Geophysical Union, the American Society of Ichthyologists and Herpetologists, the Biological Society of Washington, Sigma Xi, the American Elasmobranch Society, and the Oceanography Society.

THE OFFICE OF NAVAL RESEARCH/ NATIONAL ACADEMY OF SCIENCES INTERNATIONAL LECTURE SERIES

In an attempt to increase the exchange of information between U.S. and foreign scientists, the National Academy of Sciences, through the sponsorship of the Office of Naval Research, has initiated an international lecture series, in which distinguished U.S. scientists will speak on topics that are the "cutting edge" of science. This article describes the inaugural lecture of the series, given by Prof. Walter H. Munk of the Scripps Institution of Oceanography.

by Bernard J. Zahuranec

In recent years, it has become increasingly apparent that in science and technology the United States can learn a great deal, at least in certain areas, from other countries. Furthermore, as science has become more complex, international collaboration and cooperation is not just desirable but sometimes is essential. The Office of Naval Research (ONR) has always recognized the value of international contacts as evidenced by the two foreign field offices in London (ONREUR) and Tokyo (ONRASIA), with their information reports (*European Science Notes Information Bulletin* (ESNIB) and *Scientific Information Bulletin* (SIB), respectively). But the limited number of staff at the two field offices has made it increasingly difficult to keep abreast of science and technology activities in the areas of importance to ONR. Other approaches have been suggested to augment the existing ones, always to increase the exchange of information in easier and more cost-effective ways.

As one approach, the National Academy of Sciences (NAS), through the sponsorship of ONR, will be handling the arrangements for, and running, an

international lecture series. Initiated by ONR, the main purpose of the lecture series is to increase communication between U.S. and foreign scientists. It is planned that distinguished U.S. scientists will speak on topics that are the "cutting edge" of science, as opposed to giving a "state of the art" lecture.

One way in which increased communication will take place is, of course, the lecture itself, to be given by the U.S. scientist to the foreign audience. However, the communication is not expected to be one way. Round table discussions of scientists from that country or region will be planned in association with each lecture. The round table will discuss the state of the science and where the foreign scientists or administrators think it will be going in the next 5 to 10 years and especially what they think the hottest new research topics will be. This information will be recorded, discussed, and written up as a report to be published in the ESNIB or the SIB. Each lecture and a synopsis of results from each lecture tour will also be published as a new NAS report series.

The plan is for two lectures a year, in the spring and in the autumn, primarily rotating through three broad topic areas: oceanography, information sciences, and advanced materials research. The speakers will be chosen by ONR from suggestions provided by NAS through the aegis of a special panel handled by the Naval Studies Board. The inaugural lecture of the series, on oceanography, has just been given by Prof. Walter H. Munk of the Scripps Institution of Oceanography. Titled "The Heard Island Experiment," it was a discussion of the evidence, and lack thereof, for global warming due to climate changes and a novel approach to measure ocean warming through acoustic thermometry. The experiment itself is a feasibility study of this acoustic approach that would measure changes in low frequency sound speed at long distances as the ocean waters slowly heat up due to warming through the "greenhouse effect." If the feasibility is proven, it will presage a 10-year international monitoring effort with a number of acoustic sources and listening stations to detect the average increases in sound

speed as the oceans warm (if they are, in fact, warming up, as theories suggest).

Prof. Munk's first lecture of the series was in Washington in the Great Hall of the National Academy of Sciences. More than 250 scientists, administrators, and guests were welcomed by Dr. Fred Saalfeld, Director of ONR, who discussed the concept of the lecture series before Dr. James Ebert, Vice President of NAS, introduced Prof. Munk.

In Paris, Dr. Munk's lecture was sponsored by the French Academy of Sciences together with NAS and the lecture was delivered in the auditorium of the French Academy. However, the day before the formal lecture, Prof. Munk was asked to give an informal, impromptu version before scientists of UNESCO's Intergovernmental Oceanographic Commission. In both cases, the audiences showed much interest and asked many questions.

The four lectures in India were all enthusiastically received with many questions and a great deal of discussions. The first, in Cochin, was delivered as a plenary lecture to the Indian Acoustic Society annual meeting. An additional, informal lecture, originally unscheduled, was delivered to the scientists of the Naval Physical and Oceanographic Laboratory, whose director, Dr. V.K. Aatre, in introducing Prof. Munk, paid tribute to him as one of the world's greatest living oceanographers. The second lecture stop in India was at the National Institute of Oceanography (NIO) in Goa. There, the staff packed the auditorium to hear the lecture and showed their enthusiasm by their many questions at the end. There was a second bonus to the visit at NIO, as far as Prof. Munk was concerned: it gave him the opportunity to confirm and work out the details for Indian participation in the Heard Island Experiment.

In Delhi, Prof. Munk's lecture was not only the inaugural lecture of the NAS series but was jointly sponsored by the Indian National Science Academy and was also the inaugural lecture of a Distinguished Lecture Series of the Department of Ocean Development. Consequently, it was the secretary of that department, Dr. V.K. Gaur, who introduced Prof. Munk, again with numerous compliments and a recitation of the many accolades Prof. Munk has received. The talk itself was given at the National Physical Laboratory. The Delhi stop also included a number of visits with Government of India officials, though some of the visits were curtailed since India was in the throes of a new government, the government of VP Singh having just lost a vote of confidence in the parliament.

The final venue in India was at the Physical Research Laboratory (PRL) in Ahmedabad. Although PRL is not an oceanographic laboratory in the same sense as NIO in Goa, it does have a particularly active group in geochemistry and marine chemistry. In addition, the Centre for Environmental Education is located adjacent to the university campus. Its goal is to increase the environmental awareness of Indians, primarily through the education of primary and secondary school teachers. Prof. Munk and the team visited the centre on the first day in Ahmedabad and invited interested students and staff to come to the formal PRL lecture the next day. Their questions and discussions, added to those of the PRL staff, made for a lively final lecture in India.

The final lecture stop was in Jakarta, Indonesia. The lecture and associated program were held at the Indonesian

Agency for the Application and Assessment of Technology (BPPT is the Indonesian acronym). The audience included both the civilian and military sectors, and again, their interest prompted a number of questions and discussion after the lecture. However, the format in Indonesia was a little different in that after the discussion period that followed Prof. Munk's lecture, two Indonesian oceanographers gave research papers, one on the measurement of sea level changes in Indonesian waters and the other giving preliminary results of sound velocity measurements and calculations in the waters south of Java. Then, in the afternoon, after a working lunch, a round table discussion was held between Prof. Munk and the rest of the U.S. team and selected Indonesian marine scientists and administrators. Through these discussions as well as individual one-on-one meeting discussions over the following 2 days, the U.S. team gained an impression of present day Indonesian oceanography and plans for the coming years.

Overall, this first lecture demonstrated the potential utility of this method for increasing candid interaction between the U.S. visitors and foreign scientists. It also demonstrated that this method (or perhaps any method) would be "work intensive," requiring considerable effort to be successful.

The next two lectures in the series, tentatively to be on information sciences in the spring of 1991 and on advanced materials in the autumn of 1991, will give more opportunity to assess this process. Results from those lectures will also be reported in the ESNIB and SIB.

RECENT PROGRESS IN HIGH TEMPERATURE SUPERCONDUCTIVITY AS REPORTED AT THE INTERNATIONAL SYMPOSIUM ON SUPERCONDUCTIVITY (ISS'90)

The International Symposium on Superconductivity (ISS'90) represented a showcase of recent results in basic, technological, and applied areas of both high temperature and low temperature superconductivity. This article surveys only a modest portion of the research presented in areas of physics and chemistry, films, wire, tapes, bulk materials, and applications.

by Donald H. Liebenberg

INTRODUCTION

The International Symposium on Superconductivity (ISS'90) was held from 7-9 November 1990 in Sendai, Japan, and as anticipated represented a showcase of recent results in basic, technological, and applied areas of both high temperature and low temperature superconductivity. More than 500 people attended and some 350 papers were presented; however, this survey will represent only a modest portion of the research presented. Areas of physics and chemistry, films, wire, tapes, bulk materials, and applications will be summarized from this perspective. Since the poster paper abstracts and papers were due at the meeting, these will be reviewed in selected cases.

OVERVIEW OF PLENARY LECTURES

Two special plenary talks were given. The first special plenary talk was given by Prof. J. Clarke (Univ. of Calif.), on

"Progress Toward Electronics Technology with High T_c Films." Clarke reviewed many areas of electronics where high temperature superconductors (HTS) and low temperature superconductors (LTS) are in use or expected to be used. These areas include detectors of magnetic and electromagnetic radiation; analog devices such as three terminal control and amplifier items; and digital devices including Josephson tunnel junctions, processors, logic circuits, and memory. For HTS the need at present is for high quality films, Josephson tunnel junctions, and interconnects including crossover technology.

Clarke described historical HTS (meaning in the previous 3 to 4 years) development of Josephson junctions, beginning with the early grain boundary selection technique by R. Koch (IBM) to more recent step edge techniques such as developed at TRW. Also, junctions have been made using the multilayer structures of YBCO/PrBCO/YBCO--the barrier layer in this case of lattice-matched nonsuperconducting

praseodymium barium copper oxide (PrBCO) in the 123 phase. J. Gao (Univ. of Twente, The Netherlands) has made an a-axis film junction across a PrBCO barrier, and R. Dynes (AT&T Bell Labs), in work with the Ba-K-Bi-oxide, which is a lower temperature but isotropic superconductor, obtained a hysteretic junction with good operating characteristics at 15 K.

Clarke discussed the interconnect problem and described his successful crossover work. He has fabricated a loop pickup for coupling to a superconducting quantum interference device (SQUID). To overcome the difficulty of wet chemistry in photolithography, he has developed a 2% bromine in methanol solution and a technique for control of the edge taper in order to make good superconducting contact with the crossover lead. A 50-micron line width transformer loop has been coupled to a larger pickup loop and used with a Superconducting Technologies, Inc. (STI) SQUID. The result is a system in which the residual noise

seems to be in the SQUID; with a further factor of 3 improvement this system would be ready for incorporation into a geophysically useful instrument. A hybrid HTS pickup loop and transformer and LTS SQUID might have importance in medical studies as a more flexible unit getting the pickup close to a patient. At present the HTSSQUIDS of thallium-based films have noise characteristics at 77 K that are below rf LTS SQUIDS at higher frequencies, although not yet as good as the best dc SQUIDS at 4 K. HTS electronics is important because refrigeration is less expensive and, in the case of liquid nitrogen, the latent heat is 60 times that of liquid helium, a factor of 40 for neon at about 20 K, so the hold time for some applications could be greatly extended. Clarke expected that within 1 to 2 years HTS sensors will be available for the nondestructive evaluation industry. One interesting observation with the HTS SQUID test: the application of a small bias magnetic field reduced the noise by a factor of 10 and may be related to the pinning at larger pinning force sites. This talk was more optimistic than a recent U.S. article that had quoted Clarke, and he privately explained that recent successes in his laboratory had provided this change. Many opportunities (challenges) remain, but some of the initial concerns have been pushed aside by careful and innovative research.

The second special plenary talk, "Flux Pinning in Y-Ba-Cu-O Superconductors Prepared by Melt-Powder-Melt-Growth (MPMG) Process," was given by Prof. M. Murakami of the International Superconductivity Technology Center (ISTEC). Murakami reviewed the critical current problem, including the early work by Jin (AT&T) to melt process material and increase the critical current from about 500 A/cm² in sintered material to 2,000 A/cm² at 0.1 T field and 77 K. Above the very low H_{c1} critical field of the HTS materials, flux

penetrates, although most of the material remains superconducting until the upper critical field, H_{c2} , is reached when superconductivity is destroyed. The motion of the penetrating flux in response to an external force results in dissipation and limits the usefulness of superconductors. In fact, in a clean type II superconductor the critical current would be zero, that is, no pinning. Various pinning sites can be considered, nonsuperconducting regions such as other chemical phases (Y_2BaCuO_5 , 211 phase, or CuO in films), oxygen deficient regions (that lower T_c), or structural defects that provide a local pinning potential. Murakami has developed procedures to introduce 211 phase material into the YBCO superconductor in a fine particle dispersion in order to act as pinning sites. The increased pinning sites are important to develop the material for levitation such as would be useful for bearings and perhaps also to improve the shielding characteristics of the HTS. The process for accomplishing this was described. The result is a material that has $J_c > 10^5$ A/cm² and less sensitivity to applied magnetic fields—which otherwise decrease J_c rapidly as the weak links are quenched. But he does not yet know if the pinning is on the 211 particles or if the pinning occurs because of the strain field created by the 211 particle in the YBCO crystal structure. He noted that the present size distribution is not yet optimum and that T. Morimoto (Asahi Glass) has been able to further increase J_c with reduced 211 particle size. Murakami also discussed the flux creep and so-called irreversibility line in the applied field versus temperature curve that limits the useful region of HTS operation to less than the upper critical field value H_{c2} . (This effect is also present in LTS but the line lies very close to the H_{c2} line and it is of less practical importance.) Norwegian work has recently shown how the irreversibility line can be modified (brought

closer to H_{c2}) by the MPMG introduction of 211 phase impurities. This result has very significant technological implications as well as raising an interesting issue about the intrinsic pinning in type II superconductors. Murakami also noted that a permanent magnet can be made with this strongly pinned material that has a field of 0.5 T, which is nearly equivalent to the field of the Nd-Fe-B permanent magnets. The talk concluded with a demonstration of levitation of a goldfish bowl, of the fishing (suspension) capability of YBCO, and of the permanent magnet feature. The levitation at the banquet of Prof. Tanaka was, of course, a highlight of the technical meeting as well.

Prof. M. Klein (Univ. of Illinois) gave a plenary lecture on the electronic Raman scattering in HTS. He noted the flat featured continuum in all the cuprate superconductors. For $T > T_c$ (out to 4,000 cm⁻¹ or 0.5 eV) and gap-like features that appear for $T < T_c$. The flat spectrum hasn't been seen before in such materials as the semiconductors. He has made measurements on untwinned YBCO crystals and found the phonon features to be sharper. Detailed features were discussed for $T > T_c$ and modeled in terms of a Drude expression and a marginal Fermi liquid as described by C. Varma. Below T_c a gap is identified in freshly cleaved BiSCCO; since the penetration of light is on the order of 100 nm, the surface character is not a problem. Values of $2\Delta/kT_c$ are determined from A_{1g} spectra to be 5.5 and from B_{1g} spectra to be 8.8; similar values were found for the two phases of BiSCCO (2212) and (2223). The fit to theory is not yet satisfactory, although Klein favors a model of correct gap values for the (2223) phase and perhaps fluctuations that perturb the fit at the lower temperature phase. The nonzero extrapolation of A_{1g} and B_{1g} data needs reanalysis according to Varma and Klein.

Dr. J. Triscone (Univ. of Geneva) described the fabrication of YBCO/PrBCO/YBCO superlattices that followed on the work at Bellcore. Single target magnetron sputtering is used with 700 to 800 °C substrate temperatures where layers as thin as 2.4 nm show superconductivity. No effect on layering is expected since careful studies earlier of Y/Dy/Y fully superconducting material showed no multilayer properties. Results for 1.2 nm Y/1.2 nm Pr layer superlattices gave fairly sharp T_c , but as the Pr layer thickness increased there was a decrease in T_c and a suggestion of semiconducting behavior before the onset of superconductivity in the measured resistivity curves. As a function of Pr thickness, the T_c showed a linear decrease to 8.0 nm and then a constant value. The effect is not diffusion related, nor proximity effect related, since the Pr material is not metallic; perhaps it is a strain interaction. The magnetic field dependence is not much changed. Triscone looked at the behavior of the low temperature resistivity tails. The flux pinning energy was discussed in terms of a wide range of experiments with variations of relative thicknesses and with different applied fields. These experiments show the ability of the current technique to produce sharp interface superlattices as evidenced by careful characterization. Many other papers at the symposium were devoted to this topic and a wealth of interesting physical properties are emerging.

The two remaining plenary papers described some applications, at present with LTS but with a view towards adopting the HTS materials as properties become suitable. In the first of these papers, Dr. S. Takada (Electrotechnical Laboratory) described the Josephson digital computer operating at 4.2 K. Much of this information has been published. The most recent activities were the execution of a 128 step program with no operating failures.

The computer consists of four chips, has 4-bit word length, and includes a 1 kbit ROM and RAM. When compared to a similar machine fabricated in silicon technology, this computer had a factor of 10 better speed and a factor of 1000 less power requirement, the power being 6.2 mW for the 22,000 Josephson junction ETL-JC1. This project has been an impressive accomplishment with Nb and NbN technology, the more so because of the abandonment of Pb technology digital computer work by IBM nearly 5 years ago.

Dr. R. Schainker [Electric Power Research Institute (EPRI)] described a new program to test a superconducting magnetic energy storage system (SMES). An early U.S. effort noted the inductive energy storage competes favorably due to the quadratic dependence of energy stored on the current in the coil. A design for a pilot plant with two discharge levels, 10 MW for 2 hours and 400 MW for 100 seconds, has been completed and construction will begin next year. The initial work, a joint project between EPRI and the Department of Defense (DOD), will use NbTi wire that carries 200 kA cooled by helium in a hollow core design. Each filament will have a critical current, J_c , of 4×10^5 A/cm². No discussion of the several earlier coils, such as the Department of Energy Bonneville coil, was given, but the talk was a clear indication of the renewed interest in a moderate size coil for load smoothing and DOD-projected needs.

PHYSICS AND CHEMISTRY OF HTS

The physics and chemistry of HTS have developed into a very rich study, and it is far from clear in this author's view that the mother lode has yet been found. A table of high temperature superconductors with variations of stoichiometry would fill many pages. Fourteen oral papers and 96 posters

were presented in this topic area. Prof. M. Tachiki (Tohoku Univ.) described his recent calculations to describe the density of states (DOS) by treating the CuO₂ layer as carrying the superconductivity and the BaO and CuO layers becoming superconducting via the proximity effect. The tunneling conductance at T=0 K was shown and a similar double gap to these calculations has been reported by others. Optical conductivity was calculated with polarization sensitive to the CuO₂ layers and the CuO chains. As a function of increasing frequency in the normal state for E field perpendicular to the chains he calculated a monotonic decreasing conductivity. In the superconducting state there is a sharp onset at $\omega/2\Delta$. For polarization parallel to the chains the optical conductivity is finite below T_c and decreases to a minimum at the gap value. The Knight shift was also calculated. Using the Lawrence-Doniach model the superconducting order parameter along the c-axis was obtained and the motion of a flux line discussed. The flux line jogs between CuO₂ planes for applied fields not aligned in this plane, the jog occurring at grain boundaries. Thus, anisotropy in the critical current is predicted and agrees with the peak found at 90° in films.

Prof. W. Liang (Cambridge Univ.) described the effects of disorder and carrier density on superconductivity in the oxide systems. He echoed sentiments I had expressed upon joining the Office of Naval Research (ONR) that the complications of these structures are likely to lead to new and novel devices. Superconductivity in the layered structure is controlled by the number of carriers in the CuO₂ planes, and a defect structure leads to localization. The example with YBCO was described; superconductivity can be restored in an oxygen depleted material either by returning oxygen to the chains as a charge reservoir or by substituting calcium for yttrium. The calcium was

described as more effective in terms of a band model. In detail the shape of the bands must also be considered, and a change in the density of states (DOS) between oxygen stoichiometry (from 6 to 6.5) was noted. Other substitutions into YBCO, such as cobalt and zinc (which act differently), were discussed within this theoretical picture.

Parallel sessions prevented complete coverage of the oral papers and time prevented study of all the posters. The final oral paper included in this section was delivered by Dr. J. Jorgenson (Argonne National Laboratory). The high resolution neutron studies in the La-Cu-O, Nd-series, and La-Sr-Cu-O compounds were described in terms of a model suggesting that superconductivity occurs at a composition phase boundary. The refined neutron data show a second phase at this limit. Three types of behavior were noted in the production of samples with different physical properties but the same stoichiometry: (1) quenched, where O1 site vacancies occur in the CuO_2 planes; (2) slow cool, where $\text{La}_2\text{SrCuO}_6$ impurity phase forms; and (3) $\text{La}_{1.6}\text{Sr}_{0.4}\text{CuO}_4$ phase separates. This model calls for some revision of earlier data by J. Torrance (IBM), since the simple hole concentration is not an adequate parameter. However, when the original data are used, the current model can be shown compatible.

Of the poster papers many dealt with the increasingly detailed analysis of a limited stoichiometry or chemical substitution, with thermodynamic and magnetic properties, and with various processing techniques. One such paper was of interest since it was work at ISTECH that included Dr. J. Willis, the lone American investigator to be hosted at ISTECH. Specific heat of the yttrium (124) phase was measured and compared with (123) phase material, and the jump at T_c was found to be much less, which suggests a much lower density

of states as inferred from the Bardeen-Cooper-Schrieffer (BCS) theory. The (124) phase is also relatively HTS, that is, $T_c = 80$ K and is stable with respect to oxygen content. At present the pairing mechanism remains without complete explanation, although the electron-phonon interaction appears important. The DOS parameter over which superconductivity can appear is unknown, so such basic studies that require high resolution are essential.

A number of papers were presented on the infrared (IR) optical properties of various HTS materials. An objective is to determine the gap energy and anisotropy. A broadband mid-IR range absorption feature observed in the superconductors and thought to be unique to them was observed in non-superconducting materials by Dr. Y. Watanabe et al. (Mitsubishi Kasei). They suggest that this absorption is not directly related to superconductivity. Such a feature does not fit the usual Drude theory and new thoughts are needed. This is an excellent indication of the work that needs to be done in understanding the physical properties of these complex materials and the likelihood that interesting properties await such effort.

The main series of lanthanum, yttrium, bismuth, thallium in the copper oxides and the barium/potassium in the bismuth oxide phase were shown in the past year to be subject to wide chemical substitution that changes the physical properties. Equally exciting was the growing support for the dependence of the oxygen order (and not simply the stoichiometry) on the physical properties as discussed by M. Ohkubo et al. (Toyota), M. Klein, and J. Jorgenson. The valence studies by W. Liang to correlate with band structure and the CuO_2 plane are another example of the detailed efforts under study. The example, of T_c increasing as the Y(123) oxygen stoichiometry varies

from 7 to 6.95 and then decreasing, and the current discussion as to whether a plateau exists (it probably is dependent on oxygen order and processing conditions rather than intrinsic physics) clearly show the basic studies that are still needed. Normal state properties continue to be of interest and the Fermi liquid theories have been quite successfully applied.

WIRES, TAPES, AND BULK MATERIALS

Wires, tapes, and bulk materials were discussed in about 120 papers including 45 discussing the flux pinning. This area overlaps with both thin films and with the physics and chemistry sections. The main issues are increased critical currents and critical current densities and improved mechanical and environmental qualities. Eight oral presentations were made in parallel sessions, so selected accounts follow.

Dr. Mukai (Sumitomo Electric) discussed progress on the silver/bismuth wire. For the present wire made in lengths to 60 m, very uniform critical currents are obtained. The critical current densities, J_c , are 47,000 A/cm² at 77 K and 0 T and 11,000 A/cm² at 77 K and 1 T. A description of a small, 20-m-long magnet coil that produced 142 G at 77 K with 52 A current and 867 G at 4 K with 355 A was given. The tape is formed by using the powder-in-tube method, drawing, rolling, and sintering. These tapes are made into a stack by diffusion bonding, and six such stacks are bonded to form the wire. Wire with 1,296 strands of superconductor showed best resistance to bending strain; 0.7% bending strain after sintering did not change the critical current. J_c was 80% of the initial J_c after a 3% strain. After 20 thermal cycles there was no change in J_c . Other coils and more details of the processing were discussed. This work represents

substantial improvement and has helped to define more clearly the remaining effort.

Dr. H. Krauth (Vacuumschmelze) discussed the Bi(2212) wires and the Pb-Bi(2223) tapes. Sintering temperatures were 800 to 850 °C for the (2212) phase and 800 to 820 °C for the (2223) phase in which a thicker (2 mm) tube wall was used rather than the 1-mm-thick tube wall for the (2212) phase material. The best value of J_c for the (2223) phase material at 77 K was about 10,000 A/cm² at 0 T and 100 A/cm² at 4 T. At 4.2 K, values above 10⁵ A/cm² were obtained. The (2212) phase material showed some initial drop of J_c with field at 4.2 K but was nearly constant at 4,400 A/cm² at 10 T. This suggests little weak link behavior in the (2212) phase superconductor. As a relative fraction of the upper critical field, the relative J_c value of the Bi material exceeded that of NbTi for $B/B_c = 0.3$. The pinning forces were obtained and scaled as a power law in B with the exponent having a value of 0.75, although at higher temperatures this relationship no longer holds. The anisotropy (for B parallel or perpendicular to c -axis) was determined and increases with both field and temperature for the (2223) tape. The I - V curves showed a power law fit $V \propto I^n$ where n has values 20-30 for fields to 20 T at 4.2 K. In response to a question of high currents carried, Dr. Krauth noted some tapes have carried 500 A and 130 A at fields of 1 T.

Dr. K. Togano and others at the National Research Institute for Metals (NRIM) and Asahi Glass reported on processing and properties of Bi(2212). A doctor blade technique was used as follows: green tape was placed on a silver substrate and then fired with a profile of 890 °C, cooled to 870 °C at a controlled rate of 20 °C/hr, held for 2 hours, and then cooled. Thicknesses of up to 20 microns have shown good alignment, but for larger thicknesses only the surface material is aligned. At

77 K the (2212) phase tape has J_c of 10,000 A/cm² that drops rapidly for small fields perpendicular to the tape, but at 30 K and 12 T the value remains above 10,000 A/cm². A second technique of powder-in-tube also used processing with a controlled cooling rate of 10 °C/hr between 890 and 870 °C that gives (2212) aligned phase. The J_c values at 4.2 K are up to 10⁵ A/cm² in zero field, and the angular dependence has been studied in a magnetic field.

Dr. T. Kamo (Hitachi Research) described work with thallium, Tl-based wires with a silver sheath. A laser ablation thin film process was reported and powder methods of floating zone, plasma spray assisted, or ion beam techniques were discussed. The laser-prepared film showed J_c of 10⁵ A/cm² at zero field and 77 K with a steep drop at 1 T for fields perpendicular to the tape. For wire drawing and rolling to a thickness of 0.3 mm, less angular variation of J_c of the (2223) phase is found compared to Bi(2223) or even compared to the Tl film. The tape has random orientation. A pancake coil has been fabricated with an inside diameter of 25 mm with wire having J_c of 10,000 A/cm² at 10 G and 2,000 A/cm² at 0.1 T that generates 107 G at 77 K for a 10-m length.

Dr. N. Enomoto (Furakawa Electric) described the transport properties of BiSCCO(2212) phase wires. Silver sheathing was used, and measurements at 4.2 K up to 30 T were made. For highly oriented material, the J_c value of 10⁵ A/cm² at 77 K and 0 T was found and it dropped by an order of magnitude at 0.1 T. For 4.2 K the value of 2×10^5 A/cm² was found at 30 T with much lower values when less alignment was obtained in the processing. The angular dependence showed peaks at 90° and 270° at 77 K where B was parallel to the surface. At 4.2 K the peak was shown at 0° and diminished in fields up to 10 T. Again a single pancake coil with an inside diameter of 7 mm was

made with 40 turns of (2212) phase silver sheathed wire. Placed in a NbTi/Nb-Sn magnet, the J_c was 4,000 A/cm² at 10 T and the coil generated 460 G in this external field. At zero external field 1,520 G was generated with $J_c = 7,700$ A/cm². The core material of Bi had a final thickness of 25 to 30 microns. These results are very encouraging.

Dr. H. Kupfer (Karlsruhe) discussed the critical current characterization of melt-textured Y(123). The 211 phase precipitates were about 5 microns in size and transport J_c was 10,000 A/cm² in zero field with strong dependence on orientation at 77 K. At 4 K the J_c values were up to 10⁶, and for B parallel to the a,b plane the values were still near 10⁵ A/cm² at 10 T. There was no "fishtail" seen in the magnetization curves. In discussing the details of magnetization data, the oxygen distribution issue may play a role. The time dependence of the flux was discussed and models that do not show the same decrease at millisecond times and second times are not in agreement with the measurements. The enhancement of J_c with neutron irradiation is suggested to be related to the nonhomogeneous oxygen distribution caused by the neutron interactions. Kupfer noted the slow diffusion time for oxygen in the crystal.

Many Japanese companies have produced similar results with the wire and tape techniques as described above: Toshiba, Furakawa Electric, Mitsubishi Cable, Ividen, and Mitsui Mining & Smelting. There were others as well as government laboratories and ISTEC. This indicates the wide range of interest in HTS wire and tape development in Japan.

Together these wire, tape, and bulk results show substantial gains in current carrying capacity and critical current density in the past year. Better process control and better understanding of pinning centers and their control

do not yet seem to have reached any limit. Prospects for additional gains in properties appear very good and, as Dr. Krauth noted in his summary, these values of J_c are already within the range needed for some product development. He also pointed out in that summary that the ferromagnetic and superconducting magnetization curves have an interesting difference, a cusp on the magnetization axis for the superconductors and not along H , which gives a stable levitation compared to the ferromagnetic case and thus makes possible the design of bearings and other products.

THIN FILMS

Thin films were developed very early to have high critical current densities; the major activities have been as described by Clarke above. These activities were discussed in a series of eight oral presentations and some 62 poster papers plus a number of the flux pinning papers referred to above. The Clarke review covered most of the activities in SQUIDS, crossovers, and interconnects. Development of the superlattice and multilayer structures was covered well by Triscone, and microwave studies of thin films have progressed to the point where applications are being designed as will be discussed later. Several papers included in the applications section refer to the multilayer structures and superlattices and those will be discussed here.

Dr. T. Satoh of NEC reported on the fabrication of YBCO/PrBCO/YBCO (Y/Pr/Y) structures. These were fashioned by coevaporation techniques where the Y layers had $T_c \sim 81$ K nearly independent of the layer. Substrate temperatures of 600 °C gave smooth surfaces compared to 700 °C on which the films had rough surfaces. The base metals were deposited in an ozone atmosphere onto (001) strontium titanate. The thickness of each layer

was 30 nm. Various characterization techniques were used including scanning electron microscopy (SEM), electron microprobe, and x-ray diffraction (XRD), and a four-probe measurement was used to determine the properties. Epitaxial growth was found and little interdiffusion was observed. As yet there are no measurements of the I-V properties.

Prof. R. Gross (Univ. of Tübingen) discussed artificial layering with the YBCO and NdCeCuO material in a laser ablation process. The lattice constants for YBCO are (in Angstroms) $a=3.8177$, $b=3.8886$, $c=11.6827$ and for Nd(1.83)Ce(0.17)CuO(x) $a=b=3.946$ and $c=12.06$, so some strain is introduced that can lower the local symmetry. The critical thickness is $d_c=25.0$ nm. When $d < d_c$ then the system is coherent and for values of thickness Y/Nd 5/5 nm the $T_c=90$ K and $J_c=5 \times 10^6$ A/cm². For Y/Nd 10/20 nm, $T_c=84$ K and $J_c=1.6 \times 10^5$ A/cm² so that strain has a strong impact. For $d > d_c$ the film is incoherent and the value of J_c goes through a maximum when $d(\text{Nd})/d(\text{Y})=2$ and $d(\text{Y})=20$ nm and at a lower value of the ratio for smaller film thickness. The maximum is due to the highest density of defects, which are primarily misfit dislocations. The peak J_c value is about 10^7 A/cm² at 77 K, indicating an important improvement introduced by defects as pinning sites in this sandwich.

Prof. K. Watanabe (Tohoku Univ.) discussed flux pinning in a chemical vapor deposition (CVD) processed YBCO(123) film. J_c values of 10^6 A/cm² were obtained at zero field. Anisotropy in increasing field was observed with B parallel to the c -axis showing the steepest decline of J_c . A sharp angular dependence was observed with peaks at 90° and the sharpness increasing at the higher temperatures. A model with the Ginzburg-Landau modified effective mass fits the data quite well while the Tachiki model shows

a sharp peak as observed near T_c . The many equations presented will be left for the proceedings to report.

Prof. I. Iguchi (Univ. of Tsukuba) showed the results of fabricating Josephson tunnel junctions of the form YBCO/barrier/Pb. An in situ deposition with e-beam coevaporation was used on various substrates. A variety of barriers was used: MgO, Y₂O₃, and Al₂O₃ with thicknesses of 2 to 4 nm. On an La-Sr-Ga-O substrate with Y₂O₃ barrier the dV/dI curve shows evidence for two gaps at 4 K, the larger at less than 20 mV and the smaller due to Pb. There is a peak at $V=0$. At 69 K the peak is broad and shifted from $V=0$. Significant differences were observed between c -axis oriented films and a -axis oriented films. The critical current along c -axis orientation was between 0.05 and 0.5 mA, while along the a,b plane the value was 0.1 to 2 mA. The $I_c R$ product was small (0.01 mV), and as a function of temperature some unexpected variation was observed. The I-V curves indicate that the c -axis junction is nonhysteretic while the a -axis junction shows both types of behavior, hysteretic and nonhysteretic.

Poster papers were rich with reports of similar types of investigations by a large number of major Japanese industrial firms and included reports of two new substrate materials: (1) PrGaO(3), where the mismatch is 0.02% at 700 °C as discussed by M. Sasaura of NTT LSI Laboratories, and (2) NdGaO(3), where the mismatch is 0.37% with tetragonal structure as discussed by M. Mukaida of the same NTT Laboratories. A number of processing techniques have been developed to yield good quality films, including films on more practical substrates such as YBCO/YSZ/Hastelloy by K. Satou (Furukawa) that gave $J_c=1.4 \times 10^4$ A/cm² at 77 K, 0 T with weak link behavior as evidenced by the sharp drop with applied field. Metal organic (MO) CVD processes discussed by S. Matsuno (Mitsubishi

Electric) gave $J_c = 2 \times 10^6 \text{ A/cm}^2$ at 77 K, 0 T with $T_c = 91.7 \text{ K}$ on a strontium titanate substrate. At 30 T the value was still $2.5 \times 10^4 \text{ A/cm}^2$. Control of a- or c-axis orientation of the YBCO was evidenced by several papers including those from Fuji Electric and NTT. The angular dependence of the critical current was reported by several laboratories such as Fujikura, Hitachi, and Tohoku Electric Power Co. In an attempt to lattice match a nonsuperconducting Bi film for a tunnel junction, the work reported by T. Matsushima (Matsushita Electric) is notable. He used BiSCCO/BiSCO multilayers where a T_c (onset) of 85 K decreased to 75 K with decreasing BiSCCO thickness from 24 nm to 3 nm and the c-axis was highly oriented.

Dr. K. Endo (Electrotechnical Laboratory) discussed his work privately since there was a conflict with another session. His Bi(2223) films grown by MOCVD to a thickness of 130 nm have shown $T_c = 95 \text{ K}$ and $J_c = 3 \times 10^5 \text{ A/cm}^2$ at 77 K and 0 T. A nearly linear drop with field is found, which is less variation than given by weak links. Work has progressed on lower growth temperatures, and as noted by J. Triscone in his summary, the single layer work on Bi(2212) at ISTEK showed superconductivity with $T_c = 64 \text{ K}$ in a 3.5-nm-thick film. The ability to construct atomic layer films holds promise for the development of new materials and enhancement of their physical properties.

APPLICATIONS

Applications is, of course, where the payoff will occur for superconductivity, and the Japanese effort as evidenced at ISS'90 is very strong. The applications in the device area have been presented above except for the microwave aspects, which are more heavily supported in the United States and were reviewed at this symposium

by Prof. D. Oates (MIT). Systems applications included five oral presentations and six posters including discussions of the several large demonstration projects that the Japanese are funding.

Prof. Oates described microwave devices and in particular the surface impedance measurements and thin film stripline resonators. As was noted in the summary by J. Clarke, five microwave device units have already been sold in the United States. The surface resistance, R_s , of thin films at 77 K in low power fields with frequencies from a few GHz to nearly 100 GHz is lower by one to two orders of magnitude than copper at the same temperature. Oates described a two fluid model that can be used to extract information from stripline measurements. YBCO striplines operating at 400 MHz and at 1.5 GHz with 150-micron line width were made using off axis sputtering with substrate temperatures of 680 to 760 °C. T_c was 86.4 K. The frequency dependence with temperature was nearly constant to about 85 K and then dropped sharply, not as predicted by BCS theory. The penetration depth was 0.167 micron and the best (lowest) surface resistance was obtained with the highest substrate temperature. The low temperature approach to a constant R_s is observed in HTS and is not understood, since LTS such as niobium show the exponential decrease as expected. The power dependence was also determined and best results were obtained with the higher substrate temperature. The frequency dependence, obtained by measuring harmonics, was proportional to f^2 as expected from the above model. The nonlinear response must be considered by designers, but the present low values of the surface resistance make microwave components from HTS viable now.

Multilayer structures were discussed in four papers with a view toward device applications. Dr. C. Rogers (Bellcore) described recent work on

YBCO heterostructures and SQUID noise. An actual device of Y/Pr/Y on strontium titanate was shown to exhibit supercurrent and have an $I_c R$ product of 3 to 4 mV at 20 K. The layer thicknesses were 120 nm for Y, 2 to 50 nm for Pr, and 60 nm for the second Y layer, respectively, with an overlayer of silver of 10 nm as protective coating. A substrate temperature of 700 °C was adequate. Gold contacts were evaporated and argon ion milling was used to pattern.

Dr. Saburo Tanaka (Sumitomo Electric) showed structures of YBCO/MgO/YBCO for which atomic resolution spectroscopy had been used to look at the interfaces. At present the thinner MgO (less than 2 nm) shows a critical current but the thicker layers (greater than 5 nm) show no critical current. He was able to produce the MgO barrier onto controlled axis films of both a- and c-axis normal to the substrate for both upper and lower films of YBCO.

Dr. Y. Tarutani (Hitachi) showed work on the La-Ba-Cu-O thin non-superconducting films and used several probes to determine their characteristics such as Hall resistance. A trilayer with YBCO and this film as a barrier was made; no interdiffusion was reported and a supercurrent was observed up to 25 K.

A tunnel junction with BiSCCO(2212) single crystal as the base was discussed by Dr. K. Takahashi (Sanyo Electric). An MgO barrier and an Nb probe were placed on a cleaved and cut crystal surface. The dI/dV curves were shown and at 4.9 K the larger gap and a small peak at $V=0$ were observed. The large gap width did not change up to 60 K although the curve became very shallow, and nothing of the gap could be seen at 75 K. This gap was stated to be 60 mV (a value different from the abstract, 30 meV).

The large Super GM project to build a fully superconducting power generator was discussed by Mr. T. Ageta.

The longer range plan is to incorporate HTS materials, but the present machines, a 70-MW model and a 200-MW pilot model, are planned with LTS NbTi. They have made lower ac loss material by going to superconducting strands with a diameter of 0.05 micron in the Cu matrix. Other wire variations, such as with aluminum matrix and HTS material, are being studied. For HTS materials, their melt processed material was reported with $I_c = 139$ A at 77 K, 0 T. In 1994 a field test of the model machine is planned and both rotor and stator will be superconducting. Progress was noted with the rotor cryostat being fabricated. For this project they are not concerned with the low efficiency but want to demonstrate the technology.

The MAGLEV railway was described by Mr. J. Fujie (Railway Technical Research Institute). Some discussion was given of the planned (and authorized) 43-km-long test track including a double track section for passing tests and their plans for a 500-km/hr operating train from Tokyo to Osaka by 2003. This current project is planned for 8 years. However, there are substantial changes planned in the track propulsion magnet design, such as to provide suspension via the side wall magnets and to eliminate the separate lifting magnets. Thus the more complex side wall magnets would provide propulsion, suspension, and guidance. The stray fields in the train compartment must be reduced. This is an ambitious plan and the speeds already achieved make it attractive for future transportation.

Mr. S. Takezawa (Ship and Ocean Foundation) reported on the magneto-hydrodynamic (MHD) propelled ship. Another ambitious program, privately funded, is the catamaran hull. This has been constructed and a very flexible design for the propulsion magnets has been provided. To keep external fields to a minimum, a clever arrangement of loop coils around a cylinder has been made and a cluster of these magnets arranged to form one of two propulsors. The magnets operate at 4 T, which is not high enough to achieve needed efficiency but will allow for a full scale test of the system up to 8 knots. Already a small test tank model has been run at a field of 1.3 T with 100 A and gave a water velocity of 3 m/s. The larger system will yield 8,000 N force from each of two pods on the *Yamato 1*. Open water testing is planned for June 1991.

Two smaller projects were described. Mr. K. Okaniwa (Tokyo Electric Power) described a superconducting fault current limiter. The test was made with a 100-A, 400-V system and some 30 consecutive quenches were initiated internally without damage. There was some question as to whether the actual externally stimulated quench would behave the same. A lower loss wire is needed for the project. But this work indicates the seriousness of Japanese industry to undertake demonstration projects to determine the actual operation of new technology equipment and gain manufacturing and operating experience.

Mr. K. Hayakawa (Mitsubishi) illustrated his demonstration effort very well by describing the vertical lifter that his company has built and is testing for such planned uses as remotely lowering spent nuclear waste into storage caverns up to 1,000 ft down. The cable of conventional lifters becomes a serious additional load to be handled, and the lifter, designed with superconducting magnets (now conventional) spaced along the route, can suspend and move the test capsule that has a superconducting magnet in the persistent mode. A 5-kgm magnet in an 18.5-kgm capsule gives a total load of 23.5 kgm. The magnet has a field of 0.12 T. The plans call for a system to move 2 m/s and stop with a position accuracy of 1 mm.

CONCLUDING REMARKS

As Professor Tanaka noted in closing the session, the symposium showed the vitality of this research and development area. The prospects for high temperature superconducting systems are very high, and there is a large variety of such systems from wire magnets, motors, and large scale equipment to numerous electronic devices. The incentive for further effort remains very high indeed. The dependence of the physical properties on subtle differences in chemical composition, structure, and impurities has complicated the research but also holds promise for greater control and novel properties as the wide variety of papers indicated. I remain very optimistic that the best is yet to come.

Donald H. Liebenberg received B.S., M.S., and Ph.D. (1971) degrees from the University of Wisconsin in physics. A staff member at Los Alamos National Laboratory for 20 years (until 1981), he carried out research in the areas of low temperature physics, high pressure physics, and solar physics and contributed to major laboratory programs such as Rover (the cryogenic fluid propellant nuclear rocket reactor) and the laser fusion program where he was on the technical staff of the project director's office. Some 100 technical publications resulted from these investigations including the first application of fluctuation theory to the problem of superfluid helium film flow, the determination of the solar coronal temperatures and line-of-sight turbulence structure from precision spectroscopic measurements, and the initial studies of gases at high pressures in a diamond anvil cell. As Program Director for Solar Terrestrial Physics (on rotation to the National Science Foundation in 1967-68) and later as Program Director for Low Temperature Physics (1981-88) he was instrumental in obtaining submillikelvin research support and facilities and in supporting high temperature superconductivity discovery research. He joined the Office of Naval Research, Physics Division, in 1988 as Scientific Officer in Condensed Matter Physics. Dr. Liebenberg is a member of the American Physical Society, American Astronomical Society, American Geophysical Union, American Association for the Advancement of Science, and the Cosmos Club of Washington.

SUPERCONDUCTIVITY RESEARCH AT JAPANESE LABORATORIES

Superconductivity research at several Japanese laboratories is discussed. Many of these laboratories were visited before so that the progress can be placed in a rate-of-progress framework.

by D. Liebenberg, S. Wolf, M. Nisenoff, D. Gubser, and F. Patten

INTRODUCTION

The authors toured several Japanese laboratories involved in research on superconductivity to discuss their progress. Many of these laboratories were visited before [see D. Liebenberg, "A series of site visits on superconductivity," *Scientific Information Bulletin* 14(2), 153-167 (1989)] so that the progress can be placed in a rate-of-progress framework. These notes of this November 1990 trip primarily represent individuals' viewpoints. Some of the comments are also based on effort that was described at the International Symposium on Superconductivity (ISS'90) (see Liebenberg's article on this symposium on page 99).

MATSUSHITA ELECTRIC COMPANY

Our host at Matsushita Electric Company in Osaka was Dr. K. Wasa. He is an expert on the growth of thin films by magnetron sputtering and has written a textbook on thin film preparation that is currently being translated into English. The company slogan for 1990 was "Break Through," posted in English around the rooms we visited. Thin film work using a variety of techniques was discussed: sputtering, ion-beam, molecular beam epitaxy (MBE),

and plasma assisted chemical vapor deposition (CVD). Materials they have sputtered include ZnO, ZnSe, PLZT single crystals, and ZnO and diamond polycrystals. They are interested in electro-acoustical, optical, and solar cell devices. In high temperature superconductors (HTS) they have worked with the major series, La, Y, Bi, and Pr cuprates but not apparently with the Ba-K-Bi-O material. Substrate materials include MgO, GaAs, and others. They want to develop a low temperature process for interfacing to the semiconductors. They also want to do layer by layer film deposition to control the process and perhaps find new materials. They have developed a BiSCCO narrow bridge "three terminal device" with an electrode gate near the bridge neck, and they have shown that as the injection current from the gate electrode is increased, the critical current of the BiSCCO is reduced at 4 K. They have not yet characterized the bridge in ac operation. A second arrangement used the overlay of a metal element on the bridge neck as a heater element which, again, controlled the critical current of the bridge. A trilayer tunnel junction design of BiSCCO/BiSCO/BiSCCO was described where the insulating layer is lattice matched Bi-Sr-Cu-O. A barrier layer thickness of less than 60 nm had not yet been

made; this thickness is too thick to see much Josephson behavior. The BiSCCO thicknesses were 300 and 200 nm at a size of 20 by 20 microns. At $T=7$ K some Josephson behavior is seen, and at 30 K some steps are seen in an 11.36-GHz applied microwave field. The thinner layers of BiSCO probably short through. Some studies of a superlattice were discussed. A 3.1/2.4-nm one unit cell was prepared, and a graph of the change in resistance curve versus temperature for 3.1/10 and 6.2/10 to 100 nm films was shown; the thinner films did not exhibit superconductivity. Other materials discussed were Pb-Bi(1201) and Pb-Bi(1212), which each have $T_c \approx 40$ K. A new phase of Bi-Sr-Cu-O was shown for processing at 630°C and had $T_c = 30$ K. This material has two CuO_2 layers. The effects of the number of CuO_2 layers have been studied systematically. In touring the laboratories many research type sputtering systems were in evidence.

OSAKA UNIVERSITY

A very nice discussion was provided at Osaka University by Prof. T. Kawai, describing work on thin films, powder, and crystals. His main effort has been the atomic layer growth of HTS materials. Efforts to understand various superlattice structures and to look for

new materials were dominant themes in this laboratory. A new powder was described of Bi(2212) + Li that has $T_c = 95$ K, where the Li substitutes on the Cu sites. Single crystal work has provided good quality Bi-Sr-Cu-O(2122) crystals. The thin film work described the basic idea of providing CuO_2 layers into a wide variety of hosts by controlled atomic layer deposition. Kawai showed some examples of crystal structures built up in this way and noted especially the YBCO/LSCO superlattice that gave higher T_c values than either the YBCO/PrBCO or YBCO/NdCCO superlattices for YBCO thicknesses less than 10 nm. For the Bi(2,2,n-1,n) system when $n=1$, T_c ranges from 0 to 40 K; for $n=2$, T_c is about 80 K; and for $n=3$, T_c is about 110 K. He has inserted layers in the 2201 system to obtain $n=4,5,6$. There is phase locked growth as shown by the RHEED patterns.

SUMITOMO ELECTRIC

The visit to Sumitomo Electric and Drs. M. Nagata and K. Sato gave us a view of substantial progress in HTS wires and additional significant world class work on films and fibers. They see markets in cable supply for ship propulsion, MAGLEV, synchrotron, and magnetic resonance imaging (MRI) magnets. A table of the best known work in the area of films, bulk, and wires was given that showed for zero field the highest J_c and T_c values in the YBCO system (as well as for other materials such as Bi wires) were developed at Sumitomo Electric. For films a laser deposition system has been constructed with a KrF excimer laser; for 1-micron-thick films at 77 K and 0 T, $J_c = 8 \times 10^6$ A/cm². Polycrystalline films are a factor 300 less, while at 1 T field the single crystal film has $J_c = 1.7 \times 10^6$ A/cm² and the degradation for the

polycrystalline film is about 500. Spring contacts to the film are used.

Currently they are on two paths. One is the development of rolled tapes of Bi-Sr-Ca-Cu-O (BiSCCO) that they have produced in moderate lengths with state-of-the-art properties. They project that with the current pace of development in 1 or 2 years they will have a wire that they can market to advantage. The second path is the production of YBCO wires by continuous laser deposition process on flexible ribbons of ZrO. We saw an elaborate deposition system with take-off and take-up reels. While the properties of the polycrystalline tapes are not spectacular, they have produced films on single crystal substrates that are at the forefront. Clearly they have a commitment to a product, and with their significant position in producing various wires and cables including low temperature superconducting (LTS) cables, they will evolve a strong position in future markets.

Some details of their present efforts were given. Multifilamentary wire of Pb-BiSCCO with up to 1,296 filaments was described. The critical current and response to strain were studied. This wire showed a 20% decrease of J_c at a bending strain of 3%. The cyclic strain degradation was determined for 10 cycles; a decrease in J_c by about 10% occurred. Other wire was discussed, such as silver sheathed Pb-BiSCCO(2223) phase that showed $J_c = 10^5$ A/cm² up to 25 T. Also shown was wire that has carried a current of up to 600 A. A cryogenic lead-in is now ready that carries 1,000 A with 1 W heat leak between 4 and 30 K. They have work ongoing to describe the variation of J_c with parallel and perpendicular fields and to modify the dispersion of nonsuperconducting phases to obtain increased pinning and thus increased critical current density. For an air gap motor they have

run 7.4 A in a 16-mm-ID, 30-turn coil operated with a 200-G field at 77 K. Their latest was a 30-m length wound pancake carrying 37 A to produce 500 G.

Dr. H. Itozaki, of their Itami Research Laboratory, discussed recent film work of a HoBCO film that had $J_c = 8 \times 10^6$ A/cm² at 77 K and 0 T. A drop to 10^4 A/cm² was observed in an 8-T field normal to the film. For a BiSCCO film degradation at 0.5 T was observed. They have made only poor TI films. Their attempts to produce a superconductor/insulator/superconductor (SIS) junction are similar to those elsewhere; an MgO insulating layer of 5 nm is too thick. They have an emerging interest in microwave technology of HTS. This is a change in view by several Japanese companies that we visited; they had previously expressed disinterest based on consumer market prospects. Perhaps this interest has been stimulated by U.S. success with the development of the passive microwave device. The excellent films produced have yet to be tested for quality at microwave frequencies.

MITSUBISHI HEAVY INDUSTRIES, KOBE SHIPYARDS

We visited the magnetohydrodynamic (MHD) propulsion boat *Yamato I*. This ship, which is almost complete, represents a significant engineering job and investment by a private source. It appears that no expenses were spared to outfit this ship. The various components of the ship, conventional power plant, turbines, etc., were all displayed. It has a futuristic catamaran hull design. Two propulsion pods are designed to separate from the hull and contain the superconducting magnets and cryogenic dewar systems. These motor pods were not yet completed (although photos of the completed cryogenic system were

shown at ISS'90). The ship will be limited to 8 knots in waters of the bay, the limitation on speed due, in part, to the magnetic field, which is designed to be 4 T in each magnet. This lower field also limits the efficiency. No plans were discussed for future upgrades, although the possibility of higher field magnets could improve performance and efficiency.

INTERNATIONAL SUPER-CONDUCTIVITY TECHNOLOGY CENTER (ISTEC), SUPERCONDUCTING RESEARCH LABORATORY (SRL)

Our visit to ISTEC-SRL was hosted by Drs. Sugawara, S. Tanaka, and N. Koshizuku, who described the membership (46 full participants), working divisions (six plus Nagoya), and budget (\$1,752M, Japanese FY90). The staff is assembled from the participating companies except for the division heads, and each will serve for 2 to 3 years. Of the 100 staff some 13 have Ph.D. degrees. A video was shown that described robotic sample preparation. Dr. Murakami's important results on increased pinning in the YBCO material to enhance levitation were discussed. They noted the same information that was given at ISS'90: that good pinning, levitation, suspension, and permanent magnets (the latter with a field of up to 0.5 T) have been obtained. The high temperature superconductor provides a stable field for levitation. The pinning effect works between H_{c1} and H_{c2} , whereas the Meissner effect only works fully to H_{c1} . Work has centered on introducing finer 211 phase dispersion by modification of the processing techniques and by changing the starting composition somewhat. The addition of silver reduces the tendency for cracking, a problem with other melt

texturing processes. The silver also reduces the field dependence of J_c in the YBCO. An important result was the shift of the irreversibility line with processing condition changes, indicating that this line is not intrinsic to the material but may depend on pinning centers or defects of some sort in the material. The critical state model could be used to describe the new experiments. In thin film work they conclude that the Bi is best constructed on a layer by layer basis, and they have modified the frequency of the rf sputtering to achieve lower substrate temperatures by going to a frequency of 94 MHz so that the self-bias voltage can be reduced and the loss of oxygen controlled. In the laser deposition process they have used a bias voltage to reduce the normal state resistance of the film with +300 V.

In our tour of the laboratory facilities we were surprised that the synthesis and preparation room was off limits due to secrecy, and for similar reasons it was not possible to visit the metal organic CVD (MOCVD) apparatus. We were shown the physical measurements area where a rapidly accumulated set of well chosen equipment was available to the researchers. This whole laboratory has been put up, filled with equipment, and staffed to obtain publishable results in the course of about 2.5 years, a tribute to the organizers, Prof. S. Tanaka and others.

UNIVERSITY OF TOKYO

We visited Prof. Y. Okabe, who heads the Research Center for Advanced Science and Technology. His interest in superconductivity is the development of a three terminal device. This is again a topic that seems to have widespread priority in Japan. A Dayem type microbridge is being developed with Nb technology. He will wait until HTS material is better understood before

going to HTS. Both local campus and main campus facilities are in use. He recently moved from the main campus as part of the attempt to separate research centers from the campus. Several sophisticated circuits were discussed, including the Likharev tunneling and continuing work on the hysteretic junction. Okabe felt the Likharev type of circuit might be useful in large main-frame designs and noted that in Moscow some rudimentary circuits are being made; he will learn more when Likharev visits in a few months.

FUJITSU

The visit to Fujitsu, in Atsugi, was hosted by the director, Dr. T. Misugi, and Dr. Hasuo. In this company, whose parent is Fujitsu Limited, they are collaborating with Amdahl in the United States, ICI in England, and Siemens in Germany. A small but effective group continues work on the low temperature Josephson junction computer, although the Japanese Government [Ministry of International Trade and Industry (MITI)] project ended last January. The NEC Corporation had been responsible for the RAM memory. The Fujitsu group has built and tested a 4-bit microprocessor with their own 4-KB RAM; operated the processor to 1 GHz, which is a factor more than 10 faster than an equivalent semiconductor microprocessor; and used a factor 1/100 the power. An 8-bit microprocessor has been built using the same basic designs for the arithmetic registers and the same algorithms for the arithmetic logic unit (ALU), and they have run this unit also at 1 GHz with a 12-mW power consumption. This continuing effort is funded internally. Dr. S. Kotani provided additional details of the logic gate design that used a 1.2-micron line width. The finished chip is 5 mm square. An

innovative cryogenic design was displayed with the unit working. The chip is held at 4.7 K in pressurized liquid helium. Polyamide conductors bring the signals across the temperature gradient to room temperature with a length of about 4 cm. Then semiconductor devices are mated. On the low temperature chip signal conditioners are installed to increase the signal voltage to the mV range for semiconductor compatibility. These chips were made with research type equipment including a 10-year-old mask aligner located in a clean room of class 10000 to 1000. The timing of each part of the system has been measured: ROM read 200 ps, CROM and RAM 130 ps, multiply 240 ps, and ALU 410 ps. These tests were of critical paths and not yet a test of the full processor, in part due to needed packaging refinements. While these times would scale with word length if the same architecture is used and thus be unacceptable for a 32-bit machine, they have worked recently on a new algorithm that may provide only a factor 1.2 increase between 8- and 32-bit computations. Their long range plans would be to embed their unit into a larger mainframe system to take advantage of the significant speed increase in the basic computations.

NTT

Two locations of NTT research in HTS were visited, Atsugi and Ibaraki. At Atsugi Dr. S. Miyazawa was our host. He described their main goal to make a three terminal device in HTS material. Dr. M. Mukaida discussed epitaxial YBCO films on two new substrates, NdGaO₃ and PrGaO₃. As discussed in the ISS'90 article, the lattice mismatch with these substrates is small and the dielectric constant of each is about equivalent to LaAlO₃, $\epsilon=25$. The loss tangent of PrGaO₃ is less than LaAlO₃. A 200-nm-thick YBCO film

on NdGaO₃ had $T_c(0)=90$ K with a width of less than 1 K. The degree of orientation is high with a rocking curve width of 0.12° and c-axis normal to the surface. T_c drops with decreasing film thickness very sharply between 8 and 4 nm. The surface morphology is smooth. On PrGaO₃ the rocking curve value is about 0.24°, similar to SrTiO₃, and a 50-nm film has $T_c=90$ K. The three terminal device was discussed by Y. Tazoh with a BCS and band model type theory. He concluded from the theory that a 1-nm or less barrier is optimum for HTS materials, although the sensitivity of the model to changes in assumptions had not yet been tested. We saw excellent facilities available to this group--comparable to the best in the United States.

The second part of the NTT visit was to Ibaraki, where Dr. A. Yamaji was our host. Dr. S. Fujimori gave a general discussion of NTT and Dr. M. Hikita discussed fluctuations in HTS. This picture compared the Azlamano-Larkin theory with the Maki-Thompson theory near the transition temperature and concluded that interpreting the change in resistivity as the difference between the normal resistivity extrapolated across T_c and the measured value of resistivity was incorrect. Rather the field dependence of the resistivity should be related to fluctuations. Further discussion has been published [*Phys. Rev. B* **39**, 4756 (1989) and *Phys. Rev. B* **41**, 834 (1990)].

Single crystal study was discussed by Dr. Y. Hidaka. They have grown some of the best and largest single crystals of the high temperature superconducting materials in the world. A table of crystals that have been grown listed Ba(Pb,Bi)O₃, (Ba,K)BiO₃, LaMCuO₄, LnBa(2)Cu(3)O_x, Bi(2212), Tl(2,2,n-1,n), and LnCeCuO₄. Various sizes have been obtained; the larger LaMCuO₄ crystals have been used by Prof. Birgeneau at the neutron facility

at Brookhaven. High quality crystal growth requires an understanding of the phase diagram, and that work has also been done at NTT. Careful determination has been made to examine the homogeneity of the crystals. For the NdCeCuO crystal they find Ce is depleted near the surface and that this is less of a problem with PrCeCuO and LaSrCuO. T_c has been correlated with the Sr content and shows a sharp peak for the single crystal but a broader peak for the polycrystal. Contamination from the platinum crucible is thought to limit the single crystal data. A "skull" method for noncontact melt growth of crystals was discussed without detail. A problem not resolved is the lack of a specific heat jump at T_c for the LSCO crystal grown in this way.

We visited several laboratories and had useful discussions. Another new substrate was displayed, YAlO₃, which has very interesting and likely useful properties. The dielectric constant is 16, and a good crystal lattice match was noted, although as yet the material is so new that films have not been grown on this substrate. This group is one of the few in Japan pursuing microwave devices, presumably due to their communications responsibilities. We saw very low loss microwave films [see *Jpn. J. Appl. Phys.* **29**, L569 (1990)] of YBCO. There was discussion of films grown with a-axis or c-axis orientation, depending on the substrate temperature, 580 or 650 °C, respectively; the a-axis films had a somewhat higher normal state resistivity but a very smooth surface as examined with a scanning electron microscope (SEM). Near atomic resolution electron microscopy showed grains with dimensions of about 80 nm. This group continues to look at the infrared properties now in the cuprates and the lower T_c Ba-K-Bi-O material. This follows an exciting study of Ba-Pb-Bi-O about 6 years ago.

SUPERCONDUCTING SENSOR LABORATORY

This laboratory, in Tsukuba, was formed in March 1990 by MITI. Dr. H. Kado has come from the Electrotechnical Laboratory (ETL) to head up this new research group. The goal is to develop superconducting quantum interference device (SQUID) technology for biomagnetism. They have just moved into a new building, are still uncrating new computers including Macintoshes, and are busy gathering people from the member companies. These include a mixture of electronic, cryogenic, information systems, medical equipment, and construction companies: Hitachi, Sumitomo, Yokokawa, Shimadzu, Daikin, Seiko, Takenaka, Toshiba, and the Government (through ETL, it appears). They plan to carry out efforts in cryogenics, shielding, LTS SQUIDs, image processing, and HTS in the future. A pilot system of four SQUID sensors is being assembled from components already available from the member companies. New facilities are being set up on a university campus between Tsukuba and Tokyo (20 miles from Tsukuba). They will have a clean room for fabricating Nb junctions, electronics and image processing space, and a large shielded room of strong steel frame to reduce dc field motions and aluminum wall panels to shield rf (18 by 13 by 13 m high). They have been doing simulation studies to develop algorithms for deconvolving the multiple sensor data to describe the actual currents detected for the 1,000 sensor system being planned. We saw a demonstration of this on a new Macintosh. They showed a chip system with an 8-mm square pickup loop, SQUID with $15 \text{ fT/Hz}^{1/2}$, and a $1/f$ frequency of 1 Hz. They are operating with up to 3 kHz response. Future plans are being

developed and will include about a 30% effort in image processing. For the final plans of 10,000 or more sensors, they believe parallel processing will be essential so they are watching another government project on this topic. While early effort will be on analog systems, they are interested in a parallel path on digital SQUID since for the large scale they would like to put the initial processing on a single chip and perhaps combine with a JJ computer.

ELECTROTECHNICAL LABORATORY

Our final visit was with Dr. S. Takada, Electrotechnical Laboratory. He gave a talk on the progress of the ETL-JC1 computer (see the ISS'90 article) and reviewed that work again. After IBM dropped the Pb-based JJ computer effort, the project in Japan was scrutinized. The Osaka effort to develop NbN films was timely and was used to redirect the Japanese effort. This project has now ended and Fujitsu, NEC, and Hitachi held a news conference to describe the gains in the project. ETL recognized the difficulty of designing the microchip manually as the Fujitsu group does and so developed a computer-aided design (CAD) program to handle the Josephson junction elements and used this program to design chips for the microprocessor. Development of several chips from 1988 to 1989 resulted this year in tests of individual performance on the chips and of the complete microprocessor operating a series of 128 instructions placed into the unit. Operation chip-to-chip was not optimized and ran at 10 kHz. Future plans involve redoing the packaging to improve the speed and to improve the impedance matching. Going to a smaller line width of 0.9 micron rather than the 3 microns at present

would have significant advantages in extending from a 4-bit word to say a 32-bit word. But a large capital investment for the equipment would be required and is not likely at present. The Likharev effort was discussed, and Dr. Takada's evaluation of this effort was positive for LSI mainframe computers. However, the present effort at ETL is with the long tunnel junction soliton-like memory element, which can perform a memory function differently from the standard hysteretic Josephson junction. It appears that the digital project is now back in a research rather than a development and prototype mode.

CONCLUSIONS

Overall we found that the Japanese work in wires is leading the world and that Sumitomo is probably right at the top. LTS digital electronics remains ahead in Japan, although the best individual low temperature SQUIDs have been made by others. In HTS, passive microwave devices are clearly advanced in the United States, and Japan is just beginning to recognize a civilian market niche and starting work in this area. In active HTS the results are not so clear since good tunnel junctions operating at 77 K are not yet developed anywhere. The opportunity for American researchers to come to work in several laboratories such as NTT and ETL was discussed favorably by the Japanese. This type of interaction probably should be encouraged in selected laboratories.

ACKNOWLEDGMENT

Considerable thanks are due to our many Japanese hosts who openly discussed their research work and the status of their support and plans. Domo arigato.

Stuart Wolf is currently the head of the Materials Physics Branch of the Naval Research Laboratory (NRL) where he supervises a staff of 35 professionals doing fundamental and applied research on superconductivity, magnetism, and electronic transport. Dr. Wolf has been very active in his own superconductivity research and his work has ranged from the growth and characterization of superconducting thin films, through the development of SQUID magnetometers and superconducting infrared sensors, to a unified theoretical description of the high transition temperature cuprates. In the course of this work he has authored or coauthored over 150 technical articles, has edited 5 conference proceedings including a NATO Advanced Study Institute on *Percolation, Localization and Superconductivity*, and has a book, *Fundamentals of Superconductivity*, currently in press. He also holds five patents, has received the Navy Meritorious Civilian Service Award, and is a Fellow of the American Physical Society. He received his A.B. degree from Columbia College in 1964, and his M.S. and Ph.D. degrees from Rutgers University in 1966 and 1969, respectively. He also was a research associate at Case Western Reserve University from 1969 to 1972 and a visiting scholar at UCLA from 1981 to 1982.

M. Nisenoff is with the Microwave Technology Branch of the Electronics Science and Technology Division at NRL. He did his undergraduate work at Worcester Polytechnic Institute and his graduate

studies in physics at Purdue University. He has worked at the Ford Scientific Laboratory, Stanford Research Institute (now SRI International) and, since 1972, at NRL. His research activities have been in superconducting thin films and superconducting devices. He is currently involved in the management of a number of Department of Defense (DOD) programs in the applications of both LTS and HTS superconducting electronic devices and circuits.

Donald U. Gubser is superintendent of the Materials Science and Technology Division at NRL. He was graduated from the University of Illinois (Ph.D. in physics) in 1969 and has been employed at NRL since that time. Dr. Gubser's scientific training and personal research have been in superconductivity, magnetism, electron transport, and cryogenic properties of materials. In 1976 Dr. Gubser spent 1 year on advanced graduate training at the Swiss Federal Technical University in Zurich, Switzerland. In September 1985 he was on assignment from NRL to the National Science Foundation (NSF). At NSF he was head of the Condensed Matter Sciences Section of the Division of Materials Research. Dr. Gubser is also a professional lecturer at the George Washington University, teaching both graduate and undergraduate courses in materials sciences. At NRL Dr. Gubser has led active groups performing research in superconductivity, magnetism, electronic transport, nanoscience, physical metallurgy, composites, ceramics, and mechanics. He has published over 100 scientific

articles. In 1983 he was awarded the Naval Meritorious Service Award for his scientific leadership and research accomplishments. Dr. Gubser has recently devoted himself to beginning a new laboratory-wide initiative of High Temperature Superconductivity. This effort includes close collaborative programs with many diverse NRL, Navy, and DOD groups. He is serving on many of the government-wide panels that are focusing our national program in this area. He is the coeditor of the journal *Superconductivity* published by Plenum Press.

Frank Patten received his B.S. in physics at MIT and Ph.D. at Duke University. His thesis work was in solid-state physics on the kinetics of radiation protection in biological materials. He worked at NRL for 20 years, performing experimental research in solid-state physics. His interests were on radiation effects in wide bandgap crystalline solids and radiation protection mechanisms. He managed the Navy program on laser-hardened materials development. At the Defense Advanced Research Projects Agency (DARPA), Dr. Patten has managed programs dealing with radiation absorption in structural composites. Three principal areas were: (1) high energy laser countermeasures for ballistic missile boosters; (2) eye and sensor protection against agile, pulsed battlefield laser weapons; and (3) low signature (radar and infrared) structural composites for aircraft and missiles. He has managed the high temperature superconductivity program at DARPA since June 1989.

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